International Hydrogen Ramp-up Programme – H2Uppp

Final Report: Sustainable Production of Hydrogen and its derivatives from biogas and Green Hydrogen in Paraná, Brazil

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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1 Executive summary

H2Uppp project: scope and goals of the project

The **H2Uppp** program is a development initiative integrated by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK) of Germany. H2Uppp supports the leverage of the market for **green hydrogen** and **Power-to-X (PtX)** applications through technical and financial support given to projects along the hydrogen and derivatives chain. Through public-private partnerships (PPP), it is possible to apply imports **up to 2 million euros**, with public participation, in all stages of the hydrogen value chain: production, storage, transformation, transport and use.

In addition to PPPs, H2Uppp is dedicated to two other fields of action: **networking and project search**, through matchmaking between Brazilian and German companies, the program helps in the development of ideas, business fairs, conferences, and identification of synergies between companies and projects; and the **dissemination of knowledge and capacity building** through technical studies, specialized training and presentations at energy and finance sector events.

NIRAS International Consulting in Germany and Denmark advised on a spectrum: i) the **technical-economic feasibility study for a methanol and syncrude plant, including green hydrogen**. This study was complemented by a **financial modelling assessment and overview on international financing options** for Me-Le, especially for the methanol route, as chosen by Me-Le and GIZ. In addition, other studies were also implemented in this PPP including: **ii) H2 and PtX Certification with advisory for Me-Le, iii) advisory and study on the environmental licensing procedures for the project including a lifecycle and environmental assessments, iv) advisory on legal aspects and v) advisory and study on animal welfare aspects,** and international financial advisory to prepare the project documentation as requested by international donors and investors.

For the feasibility study GIZ invited and awarded this contract to NIRAS International Consulting (NIC) to manage the team of experts in Brazil, Denmark, Chile and Belgium to conduct FEL 1 Engineering assessments for the production of green fuels from biogas and green hydrogen. The assessment focused on a Power-to-X facility located in the Western Paraná region, and is composed of three main parts: **i) multiple biogas plants connected to cooperative of farmers, ii) a renewable energy park (PV and/or wind), and a iii) chemical synthesis factory for green fuels** including green hydrogen production. The developed plant concept is outlined in Figure 1-1 below.

This compiled report has the objective to present the main findings of each and the studies implemented for Me-Le within this Public-Private Partnership between Me-Le and GIZ in an organized and harmonized manner.

The Techno-Economic-Financial Feasbility (FEL-I Assessment)

The purpose of this assessment was to explore the techno-economic feasibility of the production of green fuels in the Western Paraná region, solving the sanitation and environmental issues in the region while addressing the significant amount of animal and agricultural waste. The relatively large biogenic carbon available in the region, from said wastes, therefore offers a unique opportunity to synthezise bio and e-fuels, as biogas from animal/agricultural waste digestion is considered one of the most cost-effective form of carbon from which green fuels can be synthetized (1).

The present summary outlines the major findings of the feasibility study, at the same time providing perspective on project reason, green fuels future market.

Why green fuels?

According to the roadmap to achieve zero carbon emission by 2050, published by the International Energy Agency (2), IEA, the market of biofuels and green hydrogen derivative fuels, e-fuels, is set to increase significantly in the future decades in order to comply with the goals of limiting global warming and relative CO2 emission. Global use of hydrogen (including hydrogen derivatives) is forecasted to expand from less than 90 Mt in 2020 to more than 200 Mt in 2030; the proportion of low-carbon hydrogen rises from 10% in 2020 to 70% in 2030, where roughly half comes from water electrolysis (green hydrogen).

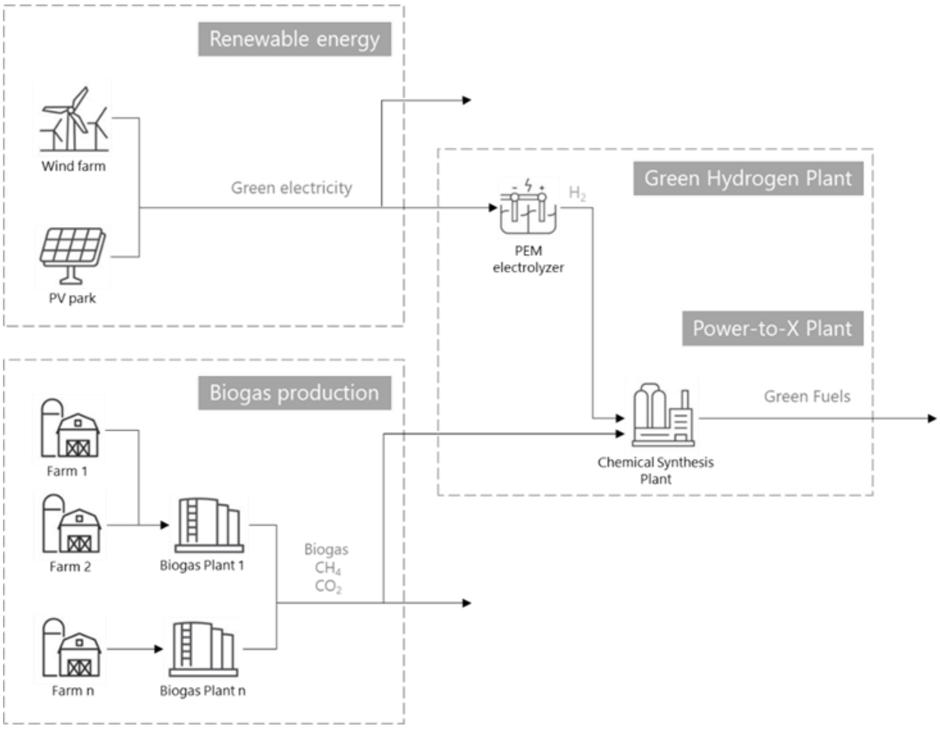
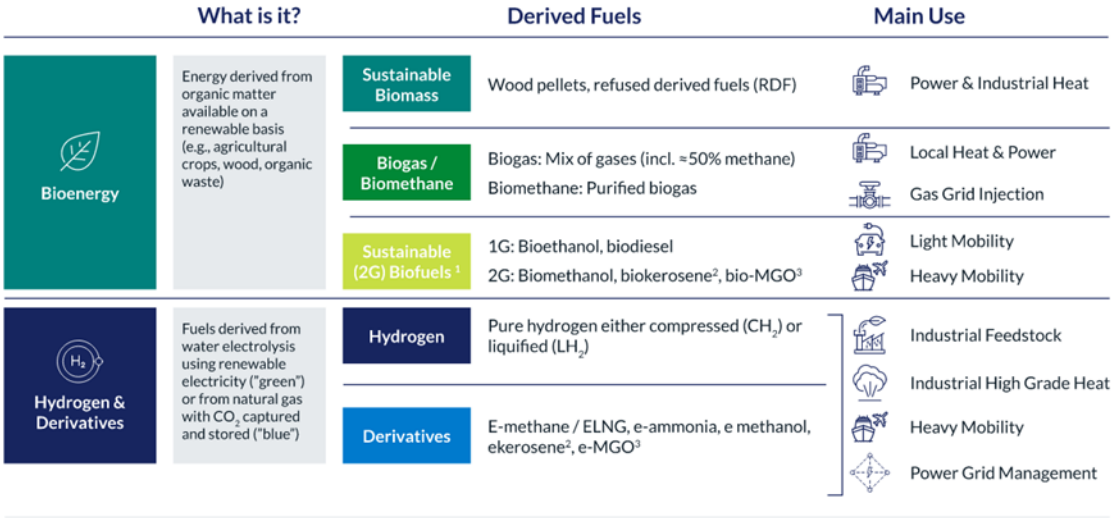


Figure 1-1 General plant concept for Green Hydrogen

Green fuels demand will increase and eventually substitute the majority of fossil oil sources both in the industrial and transportation sectors. Green fuels, including biofuels derived from biogenic carbon sources and green hydrogen derivatives (e-fuels), are going to play a major role in the decarbonization of both light and heavy mobility, and chemical industry, acting as low-carbon chemical compounds, as well as in industrial high temperature heat generation and electrical grid stabilization, as it is highlighted in following Figure 1-2.

Additionally, there are specific targets in the EU regulation for both biofuels and e-fuels utilization as highlighted in Fit for 55, RED III, RefuelEU Aviation and Maritime, among others.



Source: ENGIE Impact

Figure 1-2 Sustainable fuels and their main usages

Biofuels [1], Biokerosene [2], Bio-MGO and E-Methanol [3]

What green fuels were compared in Paraná for Me-Le?

Within the H2Uppp feasibility assessment, two types of green fuels are considered and compared, namely methanol and syncrude/SAF (substitute for kerosene), from technical and economic point of view. A comparative study is conducted to increase diversification and reduce project risk. For both green fuel products, plant layouts have been designed, carrying out production technology review and selection, as well as exploring the adaptability to variable load conditions.

The results of this comparative analysis indicate that it is economically possible to produce both SAF or methanol. With dedicated plant designs, the levelized costs are comparable with expected price ranges. However, it is highlighted that methanol route provides a larger variety in applications range, see Figure 1-3, and **therefore larger offtakers base,** as well as a **significantly higher degree of flexibility in process design and process operation**. For these reasons, a more detailed process design and economic assessment has been carried out for a green methanol plant, which includes green hydrogen, produced from water electrolysis plant. Comparative study and cases analysed are described in higher detail below in the first chapter of this document.

As can be seen in Figure 1-3, global methanol demand is significant and increasing, and renewable methanol occupies only a small fraction of the demand. Furthermore, methanol applications are pertinent to different fields and markets, not only the mobility sector. These applications will also need to be decarbonized in the future.

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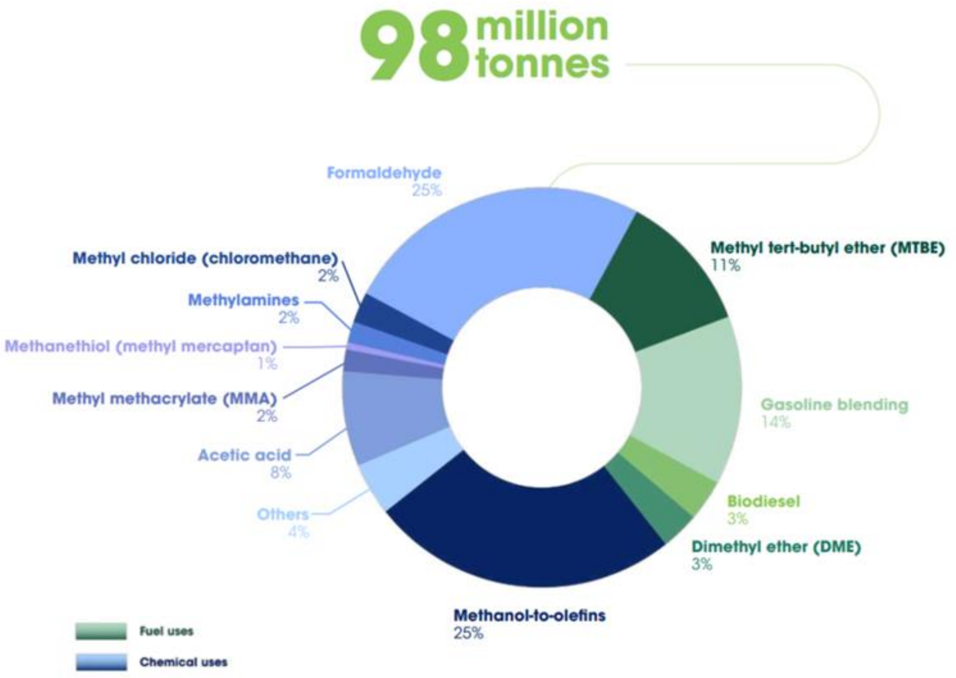
[1] biofuels: renewable fuels derived from biomass, such as biomethane

[2] Kerosene is a fuel commonly used in aviation. Biokerosene is produced from biomass, whereas e-kerosene is generated through a process involving renewable electricity, the electrolysis of water, and a renewable carbon source.

[3] Marine Gas Oil (MGO) is a fuel used in maritime applications. Bio-MGO is derived from biomass. E-MGO is generated through a process involving renewable electricity, the electrolysis of water, and a renewable carbon source. Marine Gas Oil (MGO) is a fuel used in maritime applications. Bio-MGO is derived from biomass. E-MGO is generated through a process involving renewable electricity, the electrolysis of water, and a renewable carbon source. E-methanol and e-ammonia are fuels produced through a process that utilizes renewable electricity and water electrolysis. In the case of e-methanol, a renewable carbon source is used whereas for ammonia, nitrogen separated from the air is utilized.



Source: *Based on data from MMSA (2020)*

Figure 1-3 Global methanol demand and use distribution

Which technological routes were designed and assessed in the technical (FEL-I) analysis?

A feasibility assessment was performed considering different synthetic fuels and many technologies for biogas utilization and green fuels production. The process design phase aimed to compare the feasibility of producing different green fuels: syncrude/SAF or methanol. This phase was aided by process modelling software and established kinetic models to achieve higher prediction accuracy. The decision to focus exclusively on proven technologies (higher TRL levels) reduced technological risks. Therefore, despite being theoretically more efficient, technologies such as biogas direct reforming were excluded due to current proven maturity level.

Furthermore, the design concept prioritized maximizing CO2 utilization from the biogas stream to produce green fuels, which is proven to be challenging from both technical perspectives, where certain reaction products are favoured instead of others, reducing overall yield, and economic perspective, as it is typically required to design larger synthesis loop and reactors due to the unreacted species. Having a syngas with a relative higher concentration of CO2 generally requires composition correction, in this study such intervention is carried out adding green H2 to the mixture. Therefore, the use of green hydrogen in the scenarios analysed is directly dependent to the CO2 utilization degree and may be relatively significant in size.

Which technological scenarios were assessed in the technical analysis?

Three different scenarios were proposed and investigated for converting biogas and green hydrogen into syncrude or methanol and subsequently to sustainable aviation fuels (SAF), explained as follows and shown in the figure below. The fundamental block of the process design proposed, common to all three scenarios, is the conversion of biogas into syngas (a mixture of H2, CO and CO2) and subsequently to SAF. This is realized with a combination of steam reforming unit, SMR reactor, and an adiabatic post convertor (APOC). This methodology has the advantage of creating a syngas composition more suitable for downstream synthesis processes, Fischer-Tropsch (FT) or methanol synthesis, maximizing the CO2 carbon source. Furthermore, it improves the SMR operating conditions, reducing its size as well.

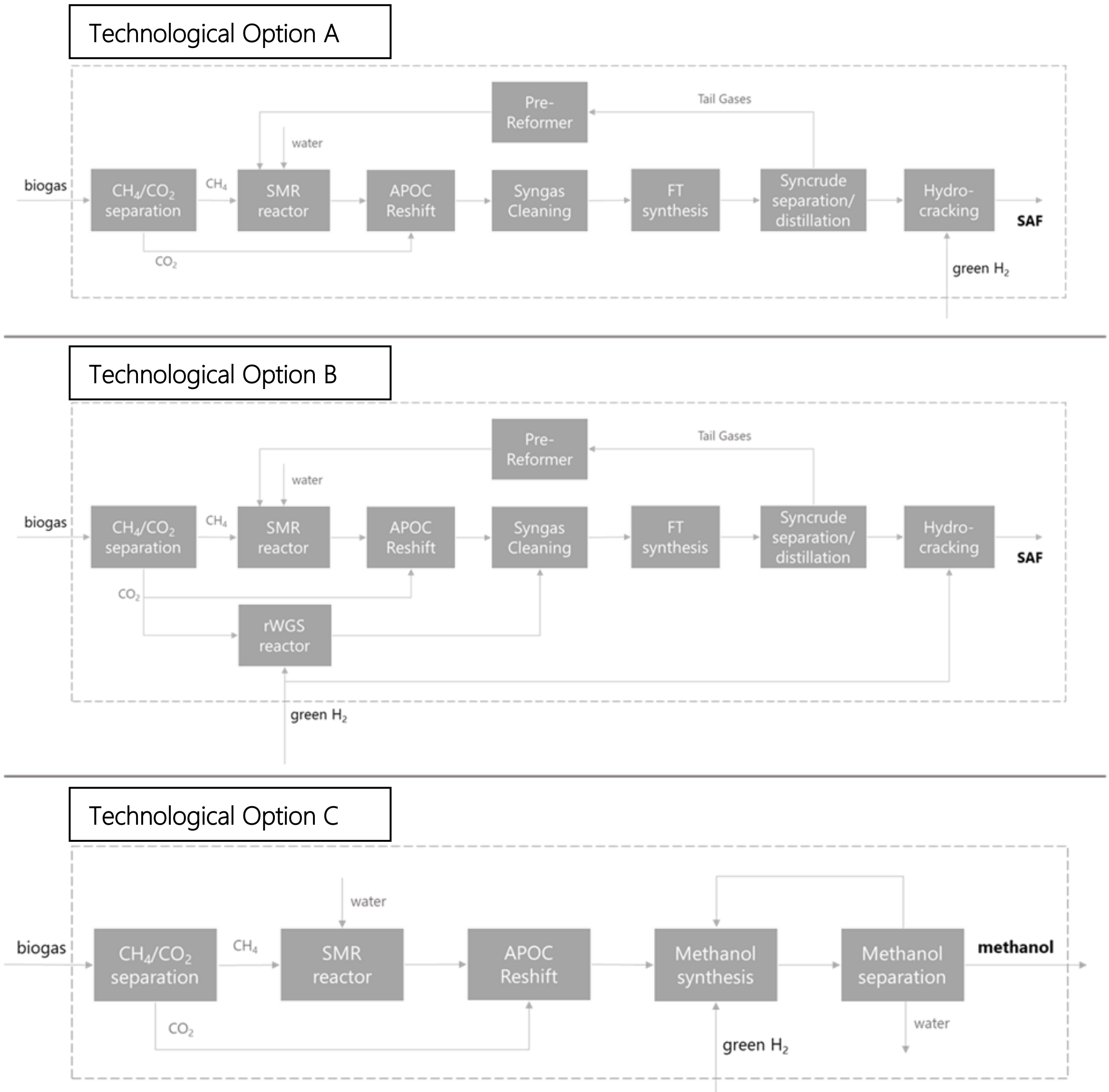


Figure 1-4 Different scenarios designed for syncrude/SAF or methanol production.

Technological options A and B present two possible version of SAF plant with different complexity degree, hydrogen utilization and overall productivity.

Technological Option A (SAF Production)

The technological option A is the simplest pathway to produce SAF, and follows the existing conventional plants configuration. Syncrude is produced through Fischer-Tropsch (FT) synthesis, distilled and hydrocracked to SAF. The tailgas and unreacted gas species from the FT loop are recovered and partially converted in a Pre-Reformer reactor before the SMR step. In this case, green hydrogen is utilized mainly in the hydrocraking step. From the technological perspective this scenario represents the highest TRL level for SAF production. Since not the entirety of available CO2 is utilized, the SAF productivity stands at approximately 365 MTD.

Technological Option B (Improve Syncrude Productivity)

The technological option B stems from the technological option A layout and intends to maximize the CO2 carbon source to improve syncrude productivity. Some of the CO2 is indeed fed to a rWGS unit together with a relevant stream of green hydrogen, to promote generation of CO rich syngas, which is then mixed with H2 rich syngas from the SMR side. Size of SMR and rWGS is optimized to achieve the correct syngas composition at the FT reactor entry. Tail gases and unreacted gases recovery layout, out of FT reactor, is kept the same as in Scenario A. SAF productivity compared to scenario A is largely improved and sets at approximately 528 MTD, configuration complexity and component size is also significantly increase.

Technological Option C (Methanol Production)

Methanol synthesis configuration, technological option C, is composed of the same SMR-APOC syngas producing block. In this case, the plant configuration presents less units and dimished complexity; the latter is to be attributed to the less strict requirements for syngas composition at the entry of the methanol synthesis loop. A certain, not negligible, fraction of CO2 can be sustained by traditional methanol reactors and effectively converted to methanol. Significant amount of green hydrogen is also utilized in the methanol synthesis loop to fully employ the CO2 from biogas, adjust the syngas composition and therefore maximizing the methanol productivity.

The technological option C layout is also characterized by a large recycle of unreacted components. However, this affects only the methanol syntesis loop and not the other reactors/steps, avoiding larger size for those components. Keeping the reduction of these gases similar to the syncrude production process. Methanol productivity is approximately 1060 MTD.A feasibility assessment was performed considering different synthetic fuels and many technologies for biogas utilization and green fuels production.

What green fuels price ranges are expected in the future?

Green fuels prices, including both bio-fuels and e-fuels, currently and for the next decades are **encumbered by a significantly large uncertainty**. The green fuel market, especially for the e-fuels case, is currently in a start-up phase.

Therefore, a relative large deviation in forecast is to be expected. Considering the methanol case first, according to many international reports and references, the projected price of e-methanol in the near future is attending between 820 USD/ton and 1620 USD/ton, (1), (3), depending on regionality, cost of electricity and cost of CO_2 supply. In the next decades the cost of e-methanol is expected to drop as the technology, value chain and market mature to a level between 250 USD/ton and 650 USD/ton. Uncertainty on bio-methanol price is relatively smaller, as it is currently produced from biogenic carbon sources, although not at a significant scale compared to global demand; its price stands between 327 USD/ton and 1013 USD/ton (1). Also in this case, price differences are mainly attributed to regionality and cost of carbon source. It is extremely relevant to mention that green fuel prices, despite the already relatively large window of values provided by the International Energy Agency, are highly dependent on the market conditions, for example bio-methanol has been bought at around 2500 USD/ton by Mearsk in 2023 (4).

Secondly, considering SAF, current fossil-originated aviation fuel price sets around 400 USD/ton and 800 USD/ton globally. SAF production, through HEFA and Alcohol-to-Jet pathways, is still nowadays limited compared to global kerosene demand, despite interest peak after ReFuelEU Aviation initiative of 5% SAF blending by 2030 for all flights departing from European airports. Given high fluctuations in biomass supply, SAF price is oscillating between 800 USD/ton and 2400 USD/ton (5), (6), (7). E-SAF is estimated to be on a similar range, in the latter case, uncertainty is the highest.

What is the performance of the final PtX facility designed for Me-Le?

The developed final concept for green methanol production has the potential to produce 1030 MTD of methanol, selling a part as certified bio-methanol and a part as certified e-methanol, following the RFNBO directive regarding the green hydrogen derivatives. It has been estimated, as part of a class 5 cost analysis (± 50%), that for the whole facility, composed of biogas plants, RE farm, **PtX plant and infrastructures, that a total investment, CAPEX, of approximately 1.3 to 1.8 billion euros is necessary**, for these ranges the financial assessment defined four scenarios, with the last one being a variant of the Me-Le scenario. The relative levelized cost of methanol for such project stands approximately between 900 and 1200 EUR/ton, placing it well within the expected price window (given the design stage of the project there is a not negligible level of uncertainty). Further details are in Financing Modelling Chapter.

How can risk be mitigated in this project?

Given the size of the CAPEX investment for the project and in order to mitigate risks and uncertainties, it is advisable to implement a **systematic approach to the project development, with the goal of gradually reducing risk at minimal cost, to reach financinal closure**.

In the feasibility study performed, four essential points were examined and the exposed conceptual recommendations have been followed and verified. **It is to be noted that a more thorough investigation of these points is required in the successive, more detailed, design phases of the project:**

- **Technical feasibility:** the processes, technology and equipment to be employed must exhibit a high maturity level and be capable of generating production output and revenues in line with the projected capacity. Additionally, ensure a high maturity level i.e. high technology readiness level. This has been verified engaging with technology suppliers.
- **Economic viability:** the project has to demonstrate the ability to generate cash flow associated with its operation, showing that the generated revenues are sufficient to cover debt costs while also providing an attractive return rate to investors and financiers. A business model analysis has been conducted to verify the project bankability.
- **Guarantee of supply:** it is has been studied and verified that there are sufficient natural resources (water, electricity, carbon sources) to ensure the project's operation throughout the projected cash flow period. An agreement has already been signed with a consortium of farmers for the biogas supply and its purchase value.
- **Guarantee of offtake:** it must be demonstrated that there are available buyers for the products and that the market pricing considered in the project analysis reflects real market conditions. A preliminary market analysis has been conducted and several potential offtakers, both local and international, have been contacted and expressed interest.

In this phase, partners and investors are being sought to secure the necessary guarantees such as process performance and intake and offtake actors, to ensure the successful production of green fuels. In particular, given an already existing agreement for biomass supply, it is sought an offtake agreement, potentially an offtake partner to be involved directly in the project. This would establish a secure partner for the entire project value chain, from biomass to green methanol use, and would help reduce the market's demand for higher returns.

What certification and sustainability analysis was conducted for hydrogen and PtX in this Power Purchase Agreement PPA PPA?

This Project defined the production of biomethanol, syncrude and subsequent production of sustainable aviation fuels from biogenic residues (specifically pig manure). A power purschase agreement (PPA) is a long-term contract between an energy producer (generally renewable energy) and a buyer, where the producer agrees to supply electricity at a fixed price over a set period. NIRAS together with Hinicio's consulting service had the objective to **(i) describe the applicable regulatory framework that affects the development of a syncrude production value chain in Brazil and its exportation to the European market**. Additionally, **(ii) the available certification schemes to potentially be implemented in the syncrude process were identified**, with recommendations oriented to the most suitable options for the specific process, off-taker market and the client's location. As part of the analysis, (iii) potential funding opportunities for this kind of projects were also reviewed.

Regulatory Analysis

Regardless of the exported product, the specific emissions savings established by the European RED II regulation for advanced biofuels must be met to commercialize the product in the European mandatory market, following the outlined methodology for GHG emissions calculations. The assessment of application-oriented regulations revealed that progressively larger shares of SAF will be mandatory in each Member State of the EU, increasing the demand for this kind of fuel, which will require to meet the RED II sustainability requirements.

To generate a carbon-neutral growth of emissions from the aviation sector, the member States of the EU are participating in the CORSIA initiative that will provide additional sustainability requirements for the production of SAF that could have an effect in this Power-to-X project to be implemented in Brazil. **If an additional renewable hydrogen stream is introduced to the process to adjust the H2:CO ratio from the biomass-based syngas, as in the project proposed here, a fraction of the final product could be labeled as Renewable Fuel of non Biological origina (RFNBO), provided that the RED II criteria regarding emissions and electricity generation for these fuels are fulfilled.**

Certification assessment

For compliance with the RED II, **it is advisable to consider certifications with streamlined frameworks to ease certification implementation while meeting project requirements, reducing costs, and mitigating risks.** Key recommended schemes include ISCC EU, 2BSvs and REDcert. It is recommended to keep track of the latest updates and maintain a comprehensive understanding of regulations in the target market before moving forward to the selection of a specific certification system for the product.

In case of potential entry into the CORSIA SAF Market, it is emphasized an early certification and thorough compliance verification. RSB EU for biofuels is recommended as it allows preliminary coverage aligning with CORSIA SAF criteria.

If not aiming to comply with CORSIA, **leveraging certifications with minimal demands is suggested, continuing with ISCC for biofuels due to its simplicity and regional adaptability.** In case a fraction of the product can be labeled as RFNBO, synergies with the ISCC RFNBO certification scheme can be used in the latter case.

Funding opportunities

No funding opportunities were identified that entirely match the value chain or countries where the project will take place. Some alternatives to access funds include forging partnerships with companies from funding-providing countries and partnering with off-takers for syncrude production downstream in Europe, which could make the process eligible for European programs. Me-Le was recommended to seek for such options.

What are the socio-environmental implications for the H2, PtX and Green Fuels Paraná program?

The study on the "Analysis of Socio-environmental Implications" assesses the regulatory requirements of the rural sanitation, bioenergy, biofuels, H2V and PtX Program, known as Green Fuels Paraná program from Me-Le. **The main**

objective of the analyses is to assess the socio-environmental suitability of the Program and determine the formal viability of the projects in the light of current environmental legislation and regulations.

The analysis covers the facilities linked to the Green Fuels Paraná Program and results in the identification of the environmental requirements applicable to the proposed projects along the whole production chain, in the light of current regulations and legislation at country, federal state and municipal levels. **It highlights an approach to the arrangements and strategies to be applied in socio-environmental licensing processes, with a view to guiding the actors responsible for the system, in its various instances, in obtaining environmental licenses and maintaining the regularity/compliance of the projects over time.**

The assessment is based on the information provided by Me-Le Biocombunstíveis GmbH and the actors involved in these studies, as well as other data and information collected during an on-site reconnaissance trip in the municipality of Toledo and the surrounding area in the state of Paraná. **The approach taken here is conceptual and aims to establish a preliminary assessment of the viability of the production systems that are part of the Program in terms of socio-environmental aspects**, **providing guidance for Me-Le and potential investors on the best structural arrangements for environmental regularization and monitoring processes over time.**

Which infrastructures are being considered in the project for the socio-economic assessment?

The project as defined here by Me-Le GmbH is named the Green Fuels Paraná Program and it provides for the production of biogas, green hydrogen from the processing of animal waste from large-scale pig, poultry and fish farms and the production of PtX streams such biomethanol, syncrude or SAF and it is to be established in the western region of the state of Paraná.

The program's infrastructure includes the construction of rural sanitation systems using underground waste and effluent pipes, connected to 50 biogas and biomethane plants and refineries which, in turn, will supply a plant for the production of biomethanol, Syncrude (CnH2n) or sustainable aviation fuels. The final product is enriched with hydrogen (H2) made from biogas.

The current proposal for the program potentially involves **biogas producers from 18 municipalities** in the western region of Paraná. Biogas production units are planned to be geographically located in such a way as to allow the effluent to be transported by gravity, considering the insertion of structured network modules in the same micro-basin, connected to biogas plants established at suitable geographical points for receiving the effluent and also in terms of accessibility to access roads and electricity grids.

The system has a modular configuration and provides for various production structures, organized in an organizational chain involving rural producers and industrial, commercial and service structures, as well as providing for the generation and supply of electricity from wind and solar power plants with off-grid production (disconnected from the National Energy System). There is also the possibility of using the biogas and biomethane produced to inject surplus energy into the National Integrated System.

For the socio-environmental approach to the Program, in order to facilitate feasibility analyses and the definition of strategies for licensing with regulatory bodies, a non-formal division into two modules was established: **1) Primary Production Module** comprising the animal farm enterprises, rural sanitation structures and biogas and biomethane production plant enterprises; and, **2) Syncrude (CnH2n) / Green Hydrogen (H2) Production Module,** comprising the biogas transportation pipelines and the Syncrude production plant. The details are presented in the report below.

The Syncrude plant will require the supply of energy produced sustainably (wind or solar) and exclusively (*off grid*) or purchased in PPA, the requirements for certification need to be assessed. It is intended that Syncrude will be distributed for subsequent distillation and consumption, using road, rail or waterway transportation (including international transportation by ship). Therefore, the system will also include energy supply and transportation structures, considered in this work as peripheral, not included in the analysis of environmental sites in this report.

Therefore, it should be noted that the work presented here does not deal with the structures and processes related to transportation and logistics after the production of CnH2n and H2, nor does it deal with the externalities of the system such as the supply of electricity needed to run the industrial unit.

In 1.5 below is a schematic or infographic that provides an overview of the production system envisaged for the Program, taking into account the Modules described above.

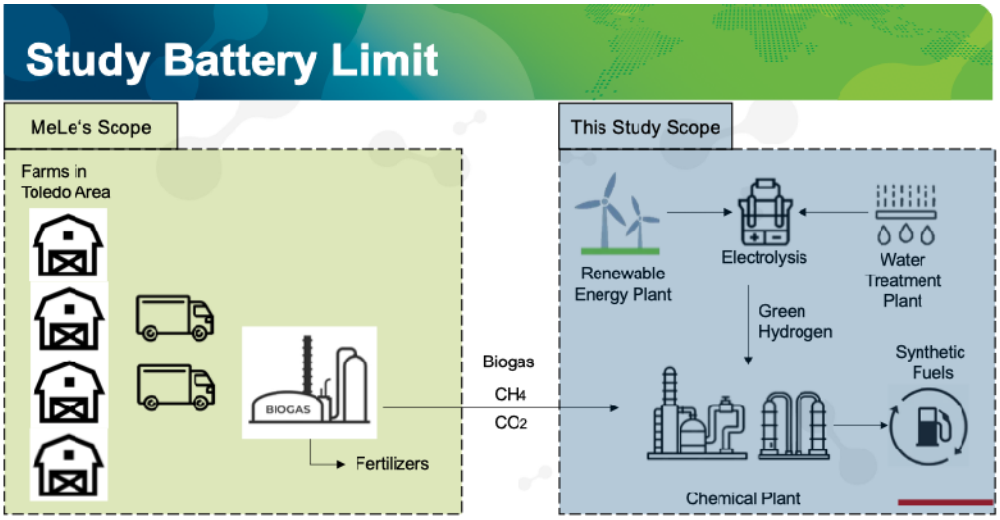


Figure 1-5 Graphical representation of the production modules planned for the Rural Sanitation, Bioenergy, Biofuels and H2V - Green Fuels Paraná Program. Source: NIRAS, 2024.

What are the scopes and approaches for the socio-environmental assessment?

The following three specific approaches have been followed for the environmental assessment.

Territorial scope

The program is designed to be applied in the western region of the state of Paraná, with the municipality of Toledo as its territorial hub, although 18 municipalities are expected to be involved. Considering that most of the projects that make up the Program will be established in state territory, in principle, the rules applicable to licensing and regularity will be state and municipal. However, it is understood that projects included in the Program that may have a potential direct impact on the Paraná River basin, or even on basins bordering the territory of Paraná with other states of the federation, may have to comply with federal licensing requirements established by IBAMA. The requirement for federal licensing will certainly depend on the size (polluting potential) and geographical position of the project.

Technical Scope

As far as the technical scope is concerned, the studies are restricted to socio-environmental issues directly related to the licensing, monitoring and regulations of the projects that are part of the Program. In other words, the analyses developed/demonstrated here are limited to the aspects relevant to licensing and regularity, and do not establish larger or more extensive scope relating to assessments of quality of life, accessibility, economic and structural development, analytical projections on environmental improvements derived from the operation of the Program, or similar.

Structural Scope relative to the model of the company

As for the structural scope, considering the modules presented above, the analyses presented here include the projects, structures and systems directly related to the biogas, biomethane and syncrude (biomethanol) production chain.

What are important legal aspects related to the project and its socio-environmental impact?

The set of rules and regulations to be followed for the purposes of licensing and the socio-environmental regularity of the project are also part of the assessment. The aim is to clarify the main elements of the legal framework of the Green Fuels Paraná Program, considering all the licensing phases, for each of the structures or undertakings included in the system (see chapters below in the corresponding studies).

It should be noted that the provisions of this report do not exhaust the spectrum of legal norms and rules that can be applied to the projects, considering that many of the activities envisaged in the Program do not have specific applicable regulations (for example, rural sanitation networks or the manufacture of Syncrude (CnH2n)), or considering that each municipality has rules that are often different and not homogeneous with regard to the socio-environmental approach. These regulatory gaps will certainly be worked on over time, even with the contribution of the current developers in conjunction with the teams from the Paraná Water and Land Institute, with the aim of establishing guidelines and parameters for licensing.

In summary, since there is a specific report on legal aspects developed within the scope of this work and signed by an expert lawyer, the main normative and legal elements applicable to the Program are listed also below.

What are the most important messages from the socio-environmental assessment?

The Green Fuels Paraná Program is currently in the planning and feasibility study phase, focusing on evaluating its environmental suitability and viability. The program involves multiple projects across 18 municipalities and requires detailed environmental licensing based on specific production alternatives and locations. The environmental analyses are preliminary and depend on further detailed information. Regardless of the production method chosen, the program will need comprehensive environmental licensing and may face significant financial impacts due to environmental compensation requirements.

What are the insights on the environmental viability of the program?

Socio-environmental Suitability: The region where the program is located faces significant environmental challenges due to intensive livestock farming. The program offers a substantial opportunity for environmental improvement by optimizing waste management and establishing rural sanitation infrastructure. This could lead to better soil, water, and air quality, benefiting the entire region and potentially serving as a model for other areas.

Formal Technical Viability and Licensing: The program is considered technically viable from an environmental licensing perspective. However, it faces challenges such as the need for specific regulations for rural sanitation, the complexity and duration of the licensing process, and the importance of project location. Despite these challenges, the program is expected to be licensable, with positive socio-environmental impacts outweighing the negatives.

All three routes display GHG Emissions reductions with different configuraitons of electricity supply and addressing the environmental problems. However, it is important to remark that this is a first assessment at an early stage of the project and therefore the analysis needs to be complemented in the future.

The Green Fuels Paraná Program lacks detailed baselines, technological boundaries, and methodological references for a more detailed GHG emissions analysis, which compromises the robustness and reliability of the results. This is due to the early phase of the project and it is an opportunity to improve in the subsequent studies.

While the program presents opportunities for innovative waste management and potential socio-environmental benefits, it also faces significant challenges in accurately determining net emissions due to insufficient data and methodological inconsistencies. Therefore, the importance of deepening the analysis when the project advances.

To validate and improve the accuracy of the program's emissions results, comprehensive field studies and adherence to established international methodologies (UNFCCC/IPCC) are essential. This includes considering all emissions, both specific and fugitive, and exploring low-carbon energy options.

What business models and financial structures were modelled for the program?

Within this Project the financial modelling and study directed efforts towards understanding and systematically and comprehensively gathering all relevant data regarding capital costs (Capex), operational and maintenance costs (Opex), and revenue estimates from the 45 biogas production plants and Biorefineries dedicated to the production of biofuels from biogas and green hydrogen, namely Syncrude/SAF and Biomethanol.

In this context, the main objective was to develop a financial model with specialized spreadsheets aimed at supporting detailed analysis of cash flows associated with the development of this program in Paraná and provide decision makers and possible future investors with the necessary tools to understand which assumptions were done and the effect on the financial performance of these investments. These tools allow for a clear and precise visualization of important financial elements necessary for strategic decision-making, thereby contributing to the effectiveness and success of the project at hand. The following scenarios were considered in the financial modelling study for Paraná:

Methanol	Scenario C.1 NIRAS data	Scenario C.2 MELE data	Scenario C.3 Uncertainty 50%	Scenario C.4 Niras Improved case	Obs.
CAPEXTotal **(Millions €)**	€ 1.824	€ 1.578	€ 1.340	€ 1.496	Total CAPEX – TCI (modules, engineering, BoP, civil and contingency)
Total OPEX **(Millions €)**	€ 312	€ 312	€ 312	€ 225,9	Total OPEX –(plant operations, utilities maintenance, depreciation and interests)
Production (Ton/h)	40	40	40	45	
Numbers of Hours	8.117	8.117	8.117	7.884	
Production (Ton / year)	324.680	324.680	324.680	354.780	
Euro / Ton	€ 1.500,00	€ 1.500,00	€ 1.500,00	€ 1.484,00	700 - 1600 Price band 700-2500
Annual Revenue (A) **(Millions €)**	€ 487,02	€ 487,02	€ 487,02	€ 526,49	
Biogas Plant	MM€ 530 / 15 anos	MM€ 530 / 15 anos	MM€ 530 / 15 anos		
Annual installment (B) **(Millions €)**	€ 35,33	€ 35,33	€ 35,33		
(A)+(B)				Scenario 1-3	
Year 2 to Year 16 **(Millions €)**	€ 522,4	€ 522,4	€ 522,4		
Year 17 to Year 20 **(Millions €)**	€ 487,0	€ 487,0	€ 487,0		
Biogas sale for second year **(Millions €)**				€ 137,78	Shall be considered in revenue before the Methanol plant is operational
Biogas Surplus Sale **(Millions €)**				€ 13,1	and biogas utilized for Methanol production
Fertilizer Sale **(Millions €)**	Only for Scenario 4	Only for Scenario 4	Only for Scenario 4	€ 44,1	
Carbon Credits **(Millions €)**				€ 14,4	
Electricity Surplus Sale **(Millions €)**				€ 1,99	
Year 2 **(Millions €)**				€ 196,30	
Year 3 to 20 **(Millions €)**				€ 600,11	
Capital sources					
Equity (E)	€ 547,2	€ 473,5	€ 402,0	€ 448,9	30% for all scenarios
Third Party Capital (D)	€ 1.276,8	€ 1.104,9	€ 938,0	€ 1.047,4	70% for all scenarios
Income tax (zero % due to applied					34% for all scenarios
Inflation					1,5% for scenario 4 - 2% for scenario 1-3
Cost of internally sourced capital (Ke)					28% for scenario 4 - 10% for scenario 1-3
Cost of capital from external sources (Kd)					12% for scenario 4 - 6% for scenario 1-3
(50% development bank + 50% private bank)					
WACC	4,8%	4,8%	4,8%	11,1%	
	This is without proft tax				
Net Present Value (NPV)	€ 341	€ 529	€ 711	€ 371	(Millions €)
Internal Rate of Return (IRR)	6,75%	8,21%	10,00%	14,65%	(%)
Payback (years)	15,0	13,3	11,5	12,3	(years)

A business model has been produced to assess the business case hypothesis and financial structure. The capital and operative costs estimation follows the indications of a FEL 1 analysis, therefore class 4 cost estimates (10), +50%, -30%. To estimate CAPEX and OPEX different methodologies were implemented, depending on the level of details of available information and topics knowledge.

Which are the final conclusions from the financial modelling assessment?

Based on the results of the analyses conducted for this economic and financial feasibility study of the projects in question, the consultants can affirm that the Biogas Central Project of 45 units demonstrates viability and is highly attractive in terms of financial return and environmental benefits.

The choice of the Biomethanol production chain is technically less complex than that of Syncrude/SAF, resulting in reduced associated economic risks and providing greater flexibility. The results of the studies demonstrate an attractive feasibility for this approach for both scenarios 3 and 4 of the financial modelling sensitivities.

The technological complexity and high capital investment associated with the levelized price of this biofuel make investment in the Syncrude/SAF plant significantly less attractive and with high financial risk. Therefore, its economic viability is considered unfeasible. The economic and financial feasibility analysis presents uncertainties due to the need for improvement in detailing the technologies employed. Therefore, further refinement is recommended as the studies progress.

It is essential to emphasize that the results presented reflect conservative scenarios, considering the applicable rates and taxes for a project of this nature. However, it is important to note that bioenergy projects, especially involving biogas, biomethane, green hydrogen, and biofuels in general, are supported by exemptions and incentives that can make the project even more attractive.

The consultants express a highly favorable opinion on the realization of this investor partnership in the projects, highlighting that the project benefits from intrinsic support from public, private, and academic institutions, making it of great importance for regional, state, and national development towards sustainability. Furthermore, this initiative strengthens ties between Brazil and Germany, providing mutual benefits in terms of environmental, economic, and social aspects for both countries, including positive impacts on local and global decarbonization.

Which considerations and recommendation where found for animal welfare practices for this project?

The Program commissioned an animal welfare study in three rural properties and one slaughterhouse in the municipality of Toledo, Paraná, with the aim of recognizing the current animal welfare practices adopted by producers of broiler chickens, dairy cattle farming, breeding swine farming, and finishing swine farming. From an initial contact, it became apparent that most producers are involved in family farming, with decades of experience in poultry, dairy cattle, or pig farming. Many of them collaborate with integrators and/or cooperatives and have shown openness to discussing animal welfare principles.

To better understand the diverse audience of the project, questionnaires were developed for each livestock activity. The responses revealed that a significant portion of the properties meets the minimum animal welfare conditions required by Brazilian legislation. However, in comparison to German and European regulations, some changes in the perspective of the breeders are still needed, along with investments in advanced technologies for farm structures.

The data collected also provided insights for developing a training session on animal welfare, which was held in late 2023 with the participation of 29 rural producers. During the event, the current concept of holistic well-being was presented, encompassing not only animal welfare but also considering human well-being and the balance of the environment where all entities coexist. The objective of the training was to encourage producers to reflect on the interconnectedness of these spheres and make wiser choices during animal management and in the environment in which they operate, ensuring that the economic activity of food production is sustainable and enduring.

The following recommendations stemmed from the animal welfare study:

- Formation of an Expert Group | Establish a group of Brazilian and German/European experts to assess, support, and guide the H2Brasil Project team on animal welfare issues and challenges in the future.
- Farmer Training | Provide training for farmers on animal welfare issues, covering both legislation and practical aspects.
- Environment/Animal Welfare Laboratory | Set up an environment/animal welfare laboratory at the region campus of UFPR (Federal University of Paraná), possibly near the H2 laboratory. This laboratory would store, maintain, repair (if necessary), and disinfect analytical instruments used in environmental, occupational, and animal welfare assessments.
- Certification Scheme | Develop and implement an animal welfare certification scheme. For compliance with German standards, for example, the QS System could be a useful scheme.
- Periodic Reports | Prepare and deliver periodic reports as per the agreed contract. The animal welfare team should collaborate and support stakeholders, the industry, other experts, and governmental bodies.

- **Reputational considerations |** Animal welfare holds great relevance for the economic success of the project, given the paramount significance of animal welfare and animal health in the public discourse on imported products in many European markets.

What are the current Stakeholders within the PPA?

In this chapter, an introduction to the main partners and participants envolved in the project will be conducted. It is important to highlight that specific partners for the renewable energy and PtX plant have yet to be identified. These partners may consist of a single entity or a combination of multiple parties.

Mele Biogas

Mele Biogas GmbH, a constituent of the mele® Group headquartered in Torgelow, Mecklenburg-Western Pomerania, is a full-service biogas provider. Operating both domestically and internationally, it specializes in tailoring bespoke solutions for biomass utilization to produce sustainable energy. Mele Biogas GmbH manages all aspects of biogas project execution, including development, planning, construction, and operational oversight, ensuring successful implementation.

GIZ

The German Society for International Cooperation (GIZ) is a service provider specializing in international cooperation for sustainable development and international education work. With over 50 years of experience, GIZ operates across diverse areas, encompassing economic development, employment promotion, energy, environment, and peace and security. Renowned for their expertise, GIZ is globally sought after by various entities, including the German Government, European Union institutions, the United Nations, private sector entities, and foreign governments. In 2021, GIZ recorded a business volume of approximately EUR 3.7 billion., with nearly 70% of their 24,977 employees being national staff working in around 120 countries.

NIRAS

NIRAS and NIRAS International Consulting is an advisory, development and engineering consulting company with over 3000 employees worldwide, present globally in over 65 offices across all continents. NIRAS clients portfolio includes Development Donors such as KFW, GIZ, DANIDA, SIDA, The European Comission, the World Bank, and numerous private companies. NIRAS conducts over 400 projects per year with a turnover of 508,8 millions of Euros in 2023. NIRAS field of expertise include international development cooperation, biogas, green fuels and green energy transitions (greensition programme), renewable energy, GIS and special analysis, automation, energy efficiency in particular for the food and beverage industries worldwide.

2 Techno-Economic and Feasibility Assessment for the production of green fuel production in the Western Paraná Region in Brazil based on green Hydrogen, renewable energy and biogenic carbon from animal and agricultural waste streams.

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Dr. Marcos Lúcio Corazza
Dr. Maurício Romani
Dr. Alessandro Checchi

The technical analysis presented in this document focuses on the feasibility assessment of green fuel production in the Western Paraná region based on green hydrogen, produced from renewable energy (RE) sources, and biogenic carbon from animal and agricultural wastes. The analysis involves:

- Process design: comparison between syncrude/SAF and methanol routes, process layout definition and simulation, economical evaluation;
- Key technologies assessment: water electrolyzers and biogas reforming reactors;
- Plant site location: water utilization potential, wind and solar energy exploration and electrical grid connection
- Economical aspects: simplified business cases analysis.

2.1 Fundamental hypothesis

The fundamental hypothesis is that methane from biogas and CO2 from biogas are handled with separate technologies to maximize the syngas production, in particular syngas with higher carbon content, and efficiently handle the high CO2 content in the biogas feed. Less mature direct reforming reactors of biogas have not been considered in this study as well as other reforming technologies, ATR, POX and similar, as they are typically associated with natural gas only reforming. Another hypothesis is the maximization of CO2 usage, given its large content in the biogas feed stream (35%-40% in molar fraction). The process design phase aimed to compare the feasibility of producing two different green fuels, syncrude/SAF and methanol. This phase has been aided by process modelling software, implementing well-established kinetic models and fully detailed equipment modelling, to achieve higher prediction accuracy. Economic evaluation based on CAPEX and OPEX has been carried out producing a simplified business case comparison using Bare Module Cost methodology (±50% accuracy) considering only the most critical and expensive components. Facilities could be powered by long-term RE PPAs in an indirect grid connection scheme with lower CAPEX compared to deploying new RE plants. However, in scenarios where green-H2 is incorporated into the product, the green fuel might be partially classified as RFNBO. Even in this high renewability grid area (>90% RE), if meeting this certification is desired, it's recommended to finance new RE plants based on local and/or remote self-production grid-tied scheme assisted by smart metering. Out of this technical and economical evaluation are left logistic organization involving transport of biomass to the plant site and transport of the green fuel product to a potential off-taker location. LCA is also out of scope for this project.

2.2 Highlights of the main findings

- Regarding the process design phase, it is found that a post-reforming technique could offer an efficient route to produce syngas with correct composition for green fuel downstream production. CO_2 from biogas is partially separated and re-injected in a later shift reactor, where reverse water gas shift reaction happens. This process scheme is provided by a potential partner.

- Regarding electrolysis, PEM is promising due to its non-dependency on alkaline chemical solutions and better flexibility when paired with RE plants when compared to alkaline technology. However, performance and specific costs of both technologies are similar (PEM slightly higher). A performance contract would be the best solution to ensure that the capacity factor of the electrolysis plant will be achieved and sustained.

- Grid-connected schemes enhance full-load electrolysis plant operativeness, which demands 33MW (green-H2 395kg/h) in the syncrude/SAF less energy-intensive scenario, up to 205MW (green-H2 3,4tons/h) for methanol. Considering the plant location conditions, in this syncrude/SAF scenario approx. 35MW of solar PV and 36MW of wind power would be sufficient to power the whole facility. For methanol, a mix of 200MW solar, 200MW wind and an extra 80MW-PPA with small-hydro/biogas plants would be needed.

- Regarding water demand and availability, despite both scenarios being water-intensive (74 m^3/h for syncrude/SAF and 237 m^3/h for methanol), the proposed location for the plant has very low water-stress risk, presenting easy access to abundant and high-quality surface and underground water sources which implies lower CAPEX/OPEX for water treatment compared to effluent usage. To improve sustainability, the high rainfall pattern (approx. 100 m^3/h) can be exploited alongside recirculation methods.

Regarding the comparison between methanol or syncrude/SAF production, it is found that with an optimized process design both green fuel production routes are economically feasible. It appears also that the CAPEX investment necessary for a SAF plant is higher with respect to a methanol plant and that the latter process route might offer a higher degree of flexibility for future investments and changes. In conclusion, it is advised to select a single process scenario for thorough evaluation.

2.2.1 Part 1: Introduction and Scope

In the introduction, a general and brief overview of the process concept was given, in which the process scope was highlighted, and some general assumptions were described.

2.2.2 Part 2: Chemical Process Analysis

In part 2, an overall overview of the complete processes for converting biogas into syncrude and methanol was presented, integrating the unit operations detailed in Chapter 7. Three process scenarios for the syncrude production and one final scenario for the methanol production are examined.
For the syncrude production, process complexity increases from base case scenario to scenario B, along with the utilization and recycling of by-products, which results in a progressive enhancement of syncrude production (from approximately 7.5 to 22 tons/h). From the CO2 utilization perspective, in the base case process and in scenario A, a significant quantity of unreacted CO2, which is removed from the syngas, is purged from the system. In contrast, in scenario B, only a negligible amount of CO2 is discharged from the process due to the presence of RWGS unit, which is responsible for increasing its conversion.

2.2.3 Part 3: Green Hydrogen Production

In this part, the aim was to suggest basic equipment specifications and preliminary sizing for green hydrogen production regarding electrolysis plants, water supply and treatment, and renewable energy (RE) for power supply.

When it comes to electrolyzers, Proton Exchange Membrane (PEM) and Alkaline (AEL) technologies present similar performance. PEM offers some technical advantages over Alkaline, mainly regarding the response to RE power oscillations, also offering a wide operation range with low minimum load (keeping the electrolysis running even if RE is just ~5%), low start-up time (<1min), high-purity H2 outlet (99,999%), low plant-level footprint (modular stacks), as well as fast deployment. In the same way, Alkaline can meet all the basic requirements for the plant too, presenting slightly lower CAPEX, but higher land footprint and KOH dependency. Market indexes suggest that both technologies' CAPEX will drop, with PEM trending from a specific cost (including BoP) of ~700 €/kWe in 2020 to ~500€/kWe estimated in 2030. AEL trending is slightly under these values. As maintenance costs are also similar, technological characteristics combined with economic analysis must be considered when making a final decision. Even more important, a performance contract would be the best solution to ensure that the capacity factor of the electrolysis plant will be achieved and sustained.

An ~24MWe electrolysis plant was considered to meet ~395kg/h-H2 needed for the lower energy-intensive syncrude production scenario, while up to 205MWe is demanded to produce ~3,4tons/h-H2 for methanol. Considering ~70% recovery rate from raw water treatment processes (superficial water quality), an estimated withdrawal of 74 tons/h of raw water are needed for the whole syncrude/SAF facilities, while up to 237 tons/h are demanded for methanol production (including electrolysis for both cases). Farming, agroindustry, and even urban wastewater could also help reach the plant's water demand. However, this would require additional costs due to advanced treatment and infrastructure needs. It is worth considering the utilization of these effluents as supplementary sources of biogas. The Arroio Guaçu sub-basin presents great remaining availability and proximity to the plant, which location is within a very low water-stress region of Brazil. As a result, despite competing for water with other activities, a grant for surface or underground water exploration is the most feasible solution for the project. To improve sustainability, the high rainfall pattern (approx. 100 m^3/h) can be exploited alongside recirculation methods.

Facilities could be powered by long-term RE PPAs in an indirect grid connection scheme with lower CAPEX compared to deploying new RE plants. However, in scenarios where green-H2 is incorporated into the product, the green fuel might be partially classified as RFNBO. Even in the high renewability grid area where the plant will be located (>90% RE), if meeting this certification is desired, it's recommended to finance new RE plants based on local and/or remote self-production grid-tied schemes assisted by smart metering. Power Purchase Agreements (PPAs) are recommended due to the importance of renewability, additionality, and geographical correlation within EU certificate directives, to reduce electricity OPEX costs. New solar and wind power plants should be located either near the industrial complex area (direct connection scheme) or in remote regions (indirect connection scheme) within the Southern Electrical Grid subsystem. Considering the plant location conditions, in this syncrude/SAF scenario approx. 35MW of solar PV and 36MW of wind power would be sufficient to power the whole facility. For methanol, a mix of 200MW solar, 200MW wind and an extra 80MW-PPA with small-hydro/biogas plants would be needed.

2.2.4 Part 4: Economic Analysis

This part provides an overview of the business cases for the various process layouts discussed in Chapter 2. The baseline for the study, was excluded due to its poor performance compared to the other scenarios. A new process for methanol production from syngas is proposed and achieves a high methanol yield by efficiently utilizing all available CO_2, but it requires a relatively high hydrogen input. Also, a simple business case analysis is conducted, comparing the different processes economically. CAPEX is estimated using quotations from comparable processes, and OPEX is calculated based on electrical utilities consumption. Market research is used to identify average price points for e-SAF and e-methanol. Methanol production via the syngas route is the preferred process scenario. Scenario A is potentially feasible but requires optimization, while scenario B is not feasible under the assumed e-SAF price.

Two sensitivity analyses are presented to provide a more comprehensive understanding of the business cases. The first one examines the impact of final product price on IRR. The methanol process is found to have the highest IRR at the lowest product price, but it is also the most sensitive to product price fluctuations. Process B only demonstrates feasibility at SAF prices above $1500/ton and is more sensitive to product price variations than Process A. The second sensitivity analysis focuses on the impact of electricity price. Process A (SAF) exhibits the lowest sensitivity to electricity price fluctuations, while the methanol process is the most susceptible. Process B is only economically feasible under the combined conditions of relatively low electricity prices and relatively high SAF product prices.

Overall, the methanol process layout is an intriguing option from an economic standpoint, but its sensitivity to both electricity and product selling point prices cannot be overlooked. Process A syncrude/SAF emerges as a more robust business case for SAF prices ranging from $1400 to $2400 per ton due to its lower reliance on green hydrogen. It is recommended to investigate scenarios involving reduced CO_2 utilization and subsequent conversion into fuels to minimize the demand for green hydrogen.

2.2.5 Part 5: Conclusions and Highlights

In this part, the main project highlights were outlined. It should be noted that the electrolyzer costs play a major role in process economics. Despite the technical feasibility of all the evaluated processes, and the economic feasibility of one of the proposed syncrude processes, the methanol process has its advantages in terms of process economics, market demand, as well as a lower complexity and higher flexibility. In spite of this process being economically more attractive, its feasibility is susceptible to a number of fluctuations in technical factors, market conditions and regulatory requirements, increasing associated risks. Optimizations and more detailed evaluations were suggested for the more promising process schemes.

2.2.6 Part 5: Technologies review

In part 6, a concise description of the primary unit operations involved in the biogas-to-syncrude, and biogas-to-methanol conversions processes is presented. The depiction and contemplation of unit operation simulations were delineated, serving as a foundational framework for the subsequent chapter, which will expound upon the interrelationships among these processes. The unit operations under consideration include water scrubbing, steam methane reforming, adiabatic post-converter, syngas upgrading, Methanol synthesis and purification, Fischer-Tropsch synthesis and syncrude purification, and pre-reformer. All these sections are technically detailed considering specifications such as temperature, pressure, reactions involved and specific parameters of individual unit operations. This overview aims to enhance the reader's comprehension of the technical specifications of the unit operations that are integrated into the process proposals described in Chapter 2.

2.3 Introduction and Scope

2.3.1 Objective

This document describes the studies and analysis carried out within the scope of a feasibility investigation for the H2Uppp project. The overall aim of the present feasibility study is to define routes to produce synthetic fuels starting from biogas, derived from animal manure, which can be achieved with highly mature process units and are economically viable.

2.3.2 General hypothesis

To perform the evaluation described in the last paragraph some assumptions were made, among which are: the process raw material is biogas, with 58% CH4 and 42% CO2, with a feed flow rate of 50 k Nm^3/h. It was also considered that CH4 and CO2 were utilized separately, as separated components from biogas. When aiming at maximization of biogas CO2 usage, (green) hydrogen is necessary for chemical conversions, more specifically to achieve the correct reactant's ratio in the synthesis step. This green hydrogen was considered to be obtained by electrolysis with renewable energy. Furthermore, only mature technologies such as steam methane reforming and methanol production from syngas were considered for the process. Regarding the product, two process routes were evaluated and compared, namely the production of syncrude (by the Fischer-Tropsch synthesis) and methanol from biogas, as shown in Figure 2.1.

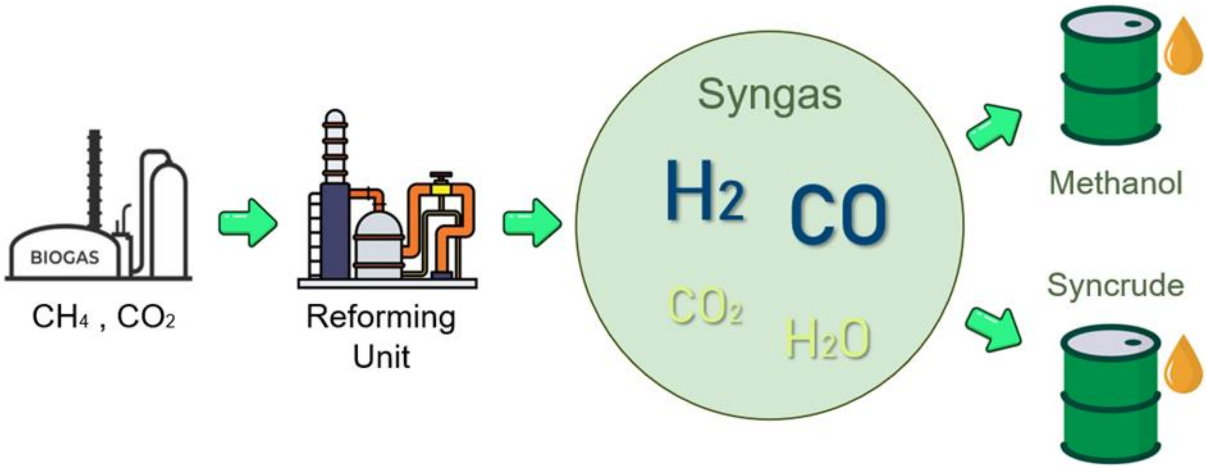

Figure 2-1 Illustrative scheme of the evaluated processes

2.4 Chemical process analysis

This chapter will provide an overview of the analyzed processes configurations for converting biogas into syncrude and methanol. The proposed main systems are presented as follows.

2.4.1 Base case – Biogas to Sycrude (no recycles)

The first process configuration proposed was defined as the base case for the conversion of biogas into syncrude, without considering any recycling for comparison purposes.

This process begins with the biogas upgrading section (water scrubber), that separates the CO2 and CH4 streams. The CH4 stream is mixed with water (in a final proportion of ~1.92 steam/CH4) and sent to the SMR. The resulting syngas stream is blended with the CO2 from the biogas upgrading step, after adjusting the CO2 to the desired pressure and temperature conditions. This mixed stream is then converted in the RWGS reactor (adiabatic post-converter), achieving a CO2 conversion of 44 %. The obtained syngas passes through a series of heat exchangers for cooling and further dehydration, with the water removal at the bottom of a flash tank. The resulting syngas stream still retains a considerable amount of CO2, that must be removed before the FT stage. For this purpose, a MEA absorber system is employed, and subsequently, the syngas temperature is adjusted before it is sent to the Fischer-Tropsch reactor. The hydrocarbons produced in the FT reactor are gradually cooled and separated in flash tanks. As previously mentioned, since no recycling is considered in this simulation, after the final separation of the syncrude fraction, a stream with a mass flow rate of 18,367 kg/h is obtained, containing both unreacted syngas and light hydrocarbons. This reference process is presented in a block flow diagram with main information of mass balance presentation.

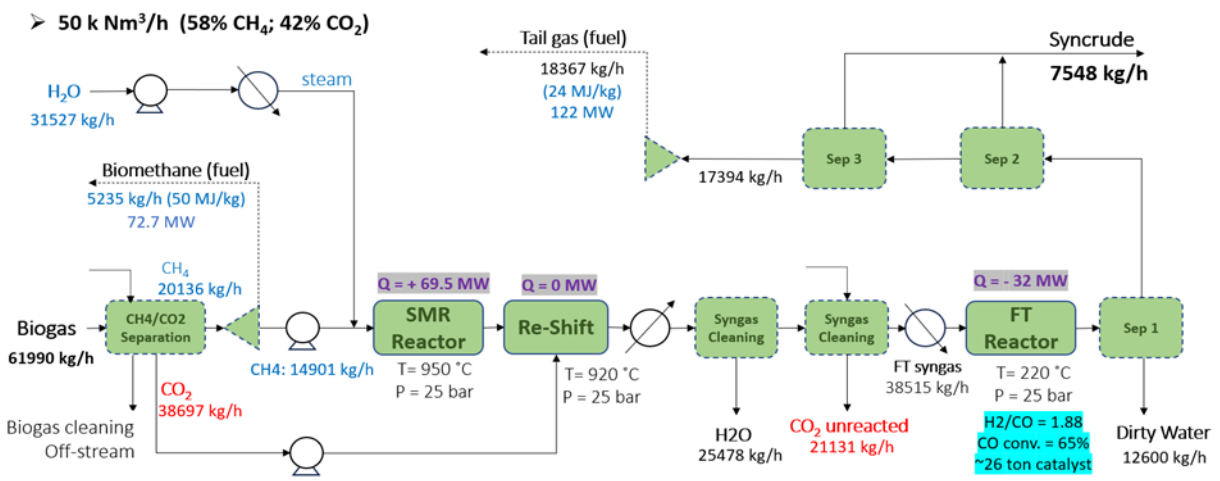

Figure 2-2 Block flow diagram for the base case process evaluated - biogas conversion to syncrude.

2.4.2 Technological option A - Process A - Biogas to Syncrude (+ recycles)

Considering that in the base case a significant quantity of unreacted syngas was obtained, a second analysis configuration was proposed with tail gas recycling. This adjustment promotes the syncrude final production and prevents the loss of the compounds within this stream. To ensure an effective recycle of tail gas, which comprises amounts of light hydrocarbons other than methane, an additional unit operation, namely the pre-reformer, is required.

The main structure of the process remains the same as the one outlined in base case scenario. Until the product separation step, after the FTS, the unit operations align with those previously detailed. However, in this case, after separating the stream containing the unreacted syngas and light hydrocarbons from syncrude, it is necessary to include a pre-heating step and a pre-reformer to convert these light hydrocarbons, excluding methane, into syngas. One more notable difference between the two processes described is that in process A, steam is introduced directly into the pre-reformer instead of the SMR. Following the pre-reformer, a portion of the stream containing the unreacted CH4, combined with the produced syngas, is blended with the fresh methane from the water scrubber before entering the SMR reactor. In this configuration, the resulting S/C ratio at the SMR inlet stands at 1.1, with a CH4 conversion of 70.6 %. The CO2 conversion in the RWGS reactor is approximately 46 %. In process A, a significant

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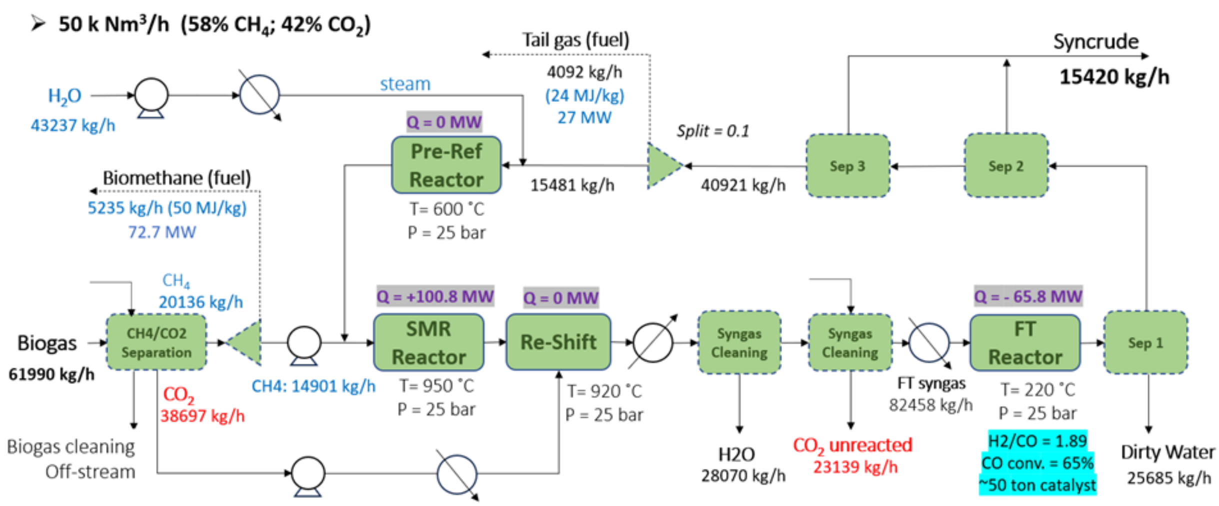

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effectively eliminated this compound, but necessitated the purging of CO_2, causing a negative impact on the process sustainability and productivity. In response to this issue, process B was proposed to address the unconverted CO_2 by incorporating an additional RWGS reactor.

In this scenario, the CO_2 stream exiting the MEA system is pre-heated and directed to a RWGS reactor, where it is converted to syngas. This intermediate product is combined with the one generated by the SMR, and the resulting process stream is then sent to the FT reactor. This configuration will increase the syncrude production and reduce the CO_2 emissions, but due to the significantly larger syngas stream, more catalyst will be required in the FTS stage, affecting the process total cost. In practice, all the CO_2 could be recycled in the process simulations. In this case, the steam to methane ratio in the SMR was 1.12, with a CH_4 conversion of 71.3 %. Also, the CO_2 conversion was 42.5 % and 76 % in the Re-Shift system and in the RWGS reactor, respectively.

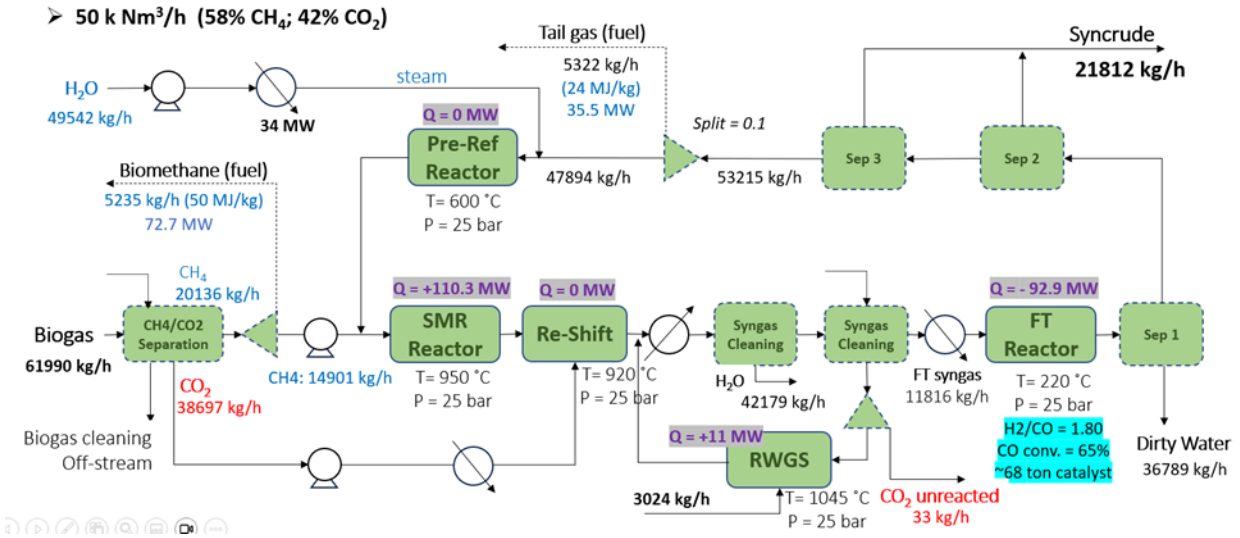

Figure 2-4 Block flow diagram for the base case with tail gas partial recycling - biogas conversion to syncrude

2.4.4 Technological option C - Process C - Biogas to Methanol

An alternative pathway for biogas utilization involves its conversion to methanol via a three-step process: steam methane reforming, water-gas shift, and methanol synthesis. This method features a high 91% recycle of unreacted components, similar to the syncrude production process. Appendix IA-B presents the process flow diagram implemented in this work for considering the technical feasibility and the preliminary economic assessment.

This process begins with the biogas upgrading section (water scrubber), that separates the CO2 and CH4 streams. The CH4 stream is mixed with water and sent to the SMR. The resulting syngas stream is blended with the CO2 from the biogas upgrading step, after adjusting the CO2 to the desired pressure and temperature conditions. This mixed stream is then converted in the RWGS reactor (adiabatic post-converter), achieving a CO2 conversion of 55 %. The obtained syngas passes through a series of heat exchangers for cooling and further dehydration, with the water removal at the bottom of a flash tank. Subsequently, the syngas temperature is adjusted before it is sent to the methanol reactor.

The product stream obtained in this step contains a mixture of unreacted syngas, CO2, CH4, water and methanol. Post-reactor, a heat exchanger takes on the role of cooling the system and condensing water and methanol. Subsequently, the chilled mixture is directed into a distillation column. Remarkably, the distillation process removes 98.5% of the water in the bottom stream. However, the inclusion of a partial condenser results in the generation of two distinct product streams. The vapor stream, laden with unreacted syngas, CO2, CH4, and trace amounts of methanol, is reintroduced into the system to enhance the conversion of methanol synthesis. This stream undergoes compression to 70 bars, achieving an impressive 91% recycle rate. Meanwhile, the liquid stream, comprising water, methanol, and dissolved CO2, undergoes additional processing. A strategically valve expands the mixture, facilitating the removal of CO2. Ultimately, a flash tank separates the remaining water and CO2 from the purified methanol, yielding a main product with a purity of 98.5%.

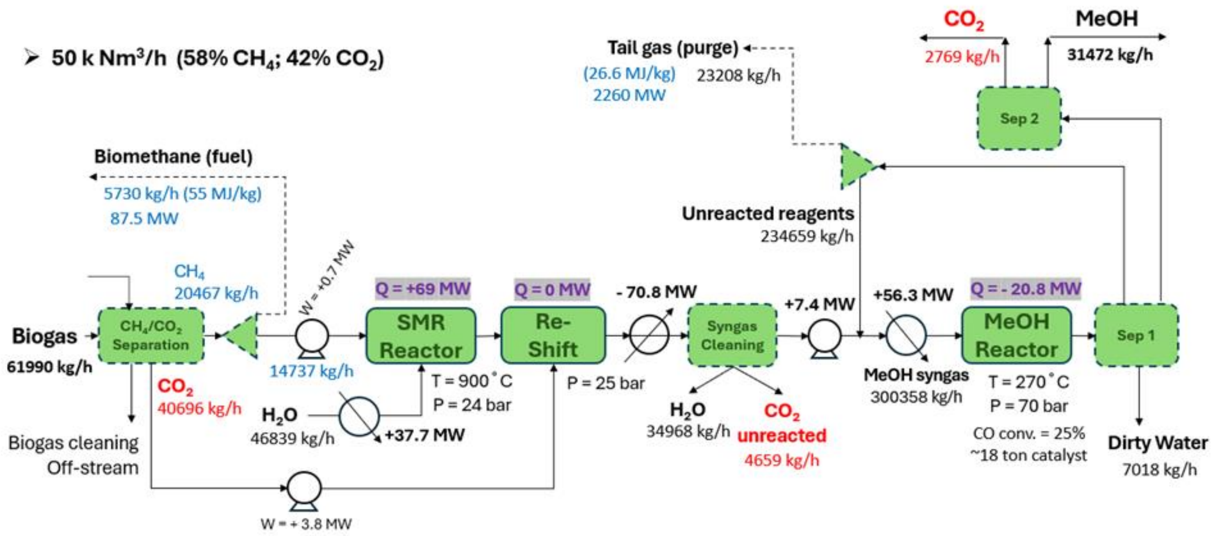

Figure 2-5 Block flow diagram for the methanol case

2.5 Infrastructure and Supply Analysis

In this part, the production of green hydrogen in the context of the H2UPPP program is discussed in terms of the electrolysis plant and technology, water supply, power demand and renewable sources. In this regard, the approximate synthetic fuel plant location was considered close to the region demarcated by Figure 2.6 (Lat 24°37'15.65"S: Lon 53°56'46.69"W).

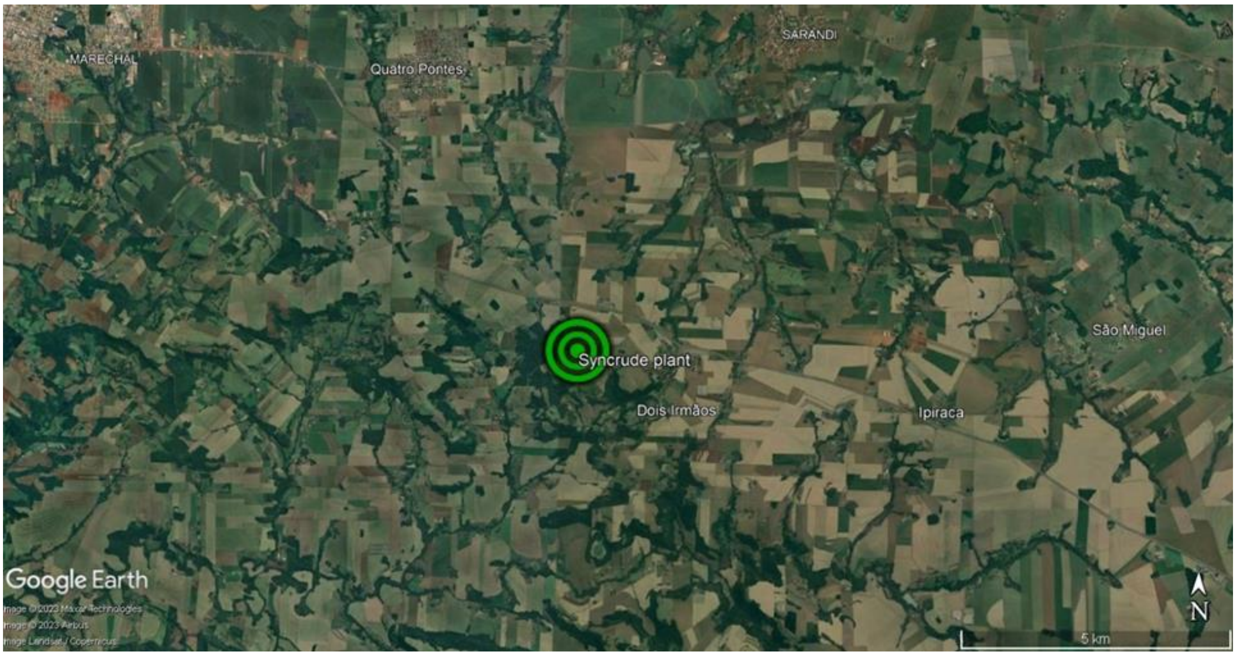

Figure 2-6 Approximate spot considered for synthetic fuel plant. Source: OESTE-PR (2023).

Table 2.1 presents the main power and water resulting requirements for two scenarios which presented the best results in terms of IRR. Assumptions that lead to the resulting values are described in the next topics.

Table 2-1 Basic requirements considered for green hydrogen in each scenario

Requirements	Syncrude/SAF	Methanol	Units
Fuel Productivity	15,4	31,5	tons/h
Green Hydrogen demand	395	3400	kg/h
Power (electrolysis) – PE	24	205	MW
Power (compression) – PC	9	45	MW
Deionized water for electrolysis (DW)	4	34	m^3/h
Water for electrolysis cooling (CW)	6	51	m^3/h
Treated water for electrolysis (DW+CW)	10	85	m^3/h
Treated water for fuel synthesis (FW)	43,3	84	m^3/h
Total treated water (TW=DW+CW+FW)	53,3	169	m^3/h
Total Raw water withdrawal (river: TW+40%)	74	237	m^3/h

To ensure a robust H_2 supply, it is recommended to design an intermediate hydrogen storage system (buffer) for both plants, as well as a compression system to ensure compatibility between the green hydrogen plant gas outlet and the synthetic fuel plant's gas inlet pressure.

To achieve better efficiency, electrolyzers should operate close to their nominal capacity most of the time. Therefore, in this study, we suggest a power supply regime that meets this requirement, with a high-capacity factor plant. This steady-state operating condition also implies that the hydrogen productivity remains at a certain minimum required value. Thus, for example tho meet methanol hydrogen demand of 3,4 tons/h, we advise sizing the electrolysis plant coupled to a storage system that can supply approximately 82 tons of hydrogen, enough to sustain a 24-hour stoppage.

A typical green hydrogen production plant consists of the following main components:

a) An electrolysis plant that uses electrical energy and water to produce hydrogen.

b) A water collection and treatment plant that provides water for the electrolysis process, as well as for other processes like cooling and steam generation of the green fuel plant.

c) A power supply system that meets the specifications and certifications required for the products of the industrial complex. This system includes power grids, and substations, and may or may not be connected to the bulk system. To achieve a zero-carbon footprint, the energy supply must also include new renewable energy generation plants that can provide the required electrical power for the electrolyzers.

The following subsections present each of the plants mentioned in this scope, focusing all analysis and recommendations on the specific context of the H2UPPP project.

2.5.1 Electrolysis Plant Basic Concept

2.5.1.1 Electrolyzer Technology comparison

At higher full-load hours, the electricity cost and overall system efficiencies become the main cost drivers rather than the investment costs (FRAUNHOFER, 2022). Figure 3.2 presents an overall Electrolysis plant CAPEX comparison for both, PEM (proton exchange membrane) and AEL (alkaline) electrolyzers technologies. These technologies were chosen due to commercial availability on large scale.

Highlights for AEL technology are:

- AEL deals with KOH dependency (price, logistics);
- Conventional AEL output pressure may demand almost 3% of Electrolyzer power, but AEL pressurized technology are also available;
- AEL H_2-output lower purity may lead to PSA higher investment if high-purity hydrogen is needed (H2Uppp might not demand high purity levels);
- Maintenance: 20 ±5 €/kW_{AC};
- Stack lifetime: AEL = 60,000 - 80,000 hours
- Deployment readiness according to supplier
- Short start-up time (under stand-by)
- Modular arrays
- Larger land footprint compared to PEM

Highlights for PEM technology are:

- No KOH dependency (price, logistics);
- High output pressure demands less power;
- High H2 purity outlet
- Maintenance: 15 ± 5 €/kW$_{AC}$;
- Stack lifetime: 40,000-70,000 hours.
- In general, fast plant deployment
- Short start-up time under stand-by (less than 1 minute)
- Modular arrays

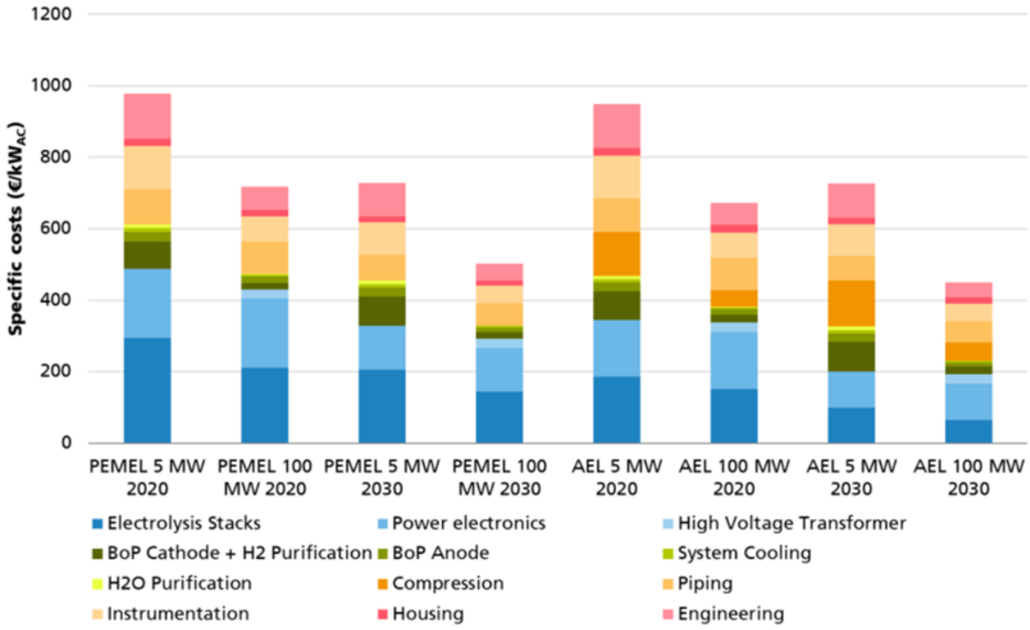

Figure 2-7 PEM vs. AEL specific costs comparison. Source: Fraunhofer (2022)

PEM technology is known as more suitable to support power supply surges and peaks (ranging from 0 to 100% in 10% per second), with a shorter start-up time (less than 1 minute) and operating with a minimum load of approximately 5% if necessary. Moreover, the H_2-output purity can achieve an index of 4.5 or even 5.0 with an output pressure of 30 bar. All these characteristics contribute to an efficiency of up to 75% in the plant's operation.

PEM electrolyzers offer some technical advantages, which are expected to be enhanced by continuous technological development and investment. Over the next decade, the next generation of PEM stacks is expected to improve plant performance significantly. Since PEM-electrolyzers are constructed using modular arrays, manufacturers can anticipate the need for future replacements without unnecessary peripheral component substitution based on their customers' requirements.

Based on a broader outlook and the cost forecast shown in Figure 2.7 (2020 PEM and AEL specific costs both near to ~700 €/kW$_{AC}$), a PEM-based Electrolysis plant with high-lifetime stacks guarantee might be a solution slightly better for projects that require flexibility, additional renewable power, and more importantly, the potential opportunity cost of emerging markets for hydrogen derivatives due to fast deployment time. Within this advisory, the Figure 3.3 flowchart presents the basic concept for a standard PEM-based Electrolysis plant.

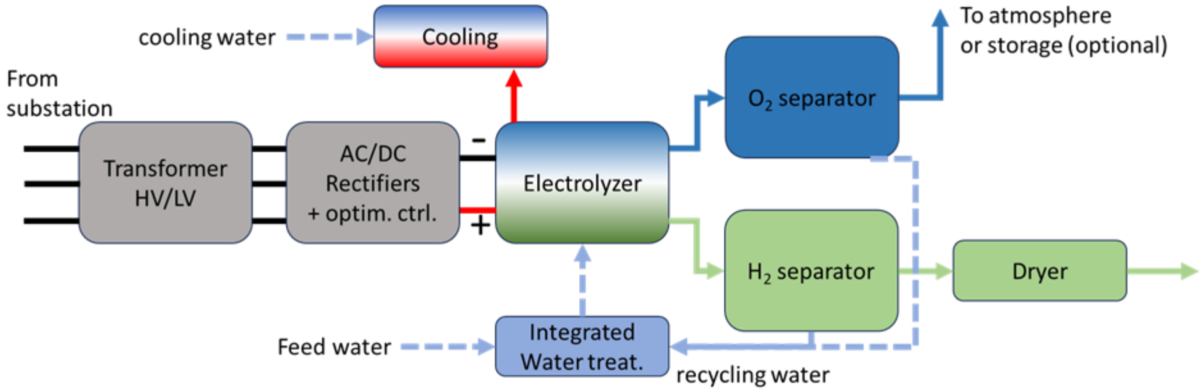

Figure 2-8 Electrolysis plant basic concept flowchart

However, an important question must be refined before any decision-making: Will the PEM electrolysis prices really drop? This is a difficult question to answer, considering that this technology demand rare minerals (like Iridium) for high performance results. So, its price is very related to this minerals market. It's also known that AEL electrolysis suppliers are aware of weak points of this technology, for instance developing and improving pressurized equipment to meet higher output pressure requirements. Technological characteristics combined with economic analysis must be considered when making a final decision. Even more important, a performance contract would be the best solution to ensure that the capacity factor of the electrolysis plant will be achieved and sustained.

2.5.1.2 PEM-based Electrolysis Plant Preliminary Sizing

To achieve a production capacity of 3,4 tons of hydrogen per hour, multiple PEM electrolyzer stations need to be coupled together. Typically, commercially available PEM electrolyzers come in sizes of up to 5 to 20MW$_{DC}$, producing around 18kg of hydrogen per 1MW$_{DC}$ installed. Therefore, to meet the hydrogen flow requirement for methanol, ~190MW$_{DC}$ would be necessary, and ~22MW$_{DC}$ for syncrude/SAF (capacity factor ~90%). Although we assume a robust power and water supply, the PEM-Stack needs stoppage time for maintenance. However, it is possible to size a plant so that the stack arrangements are switched off alternately, keeping the plant's hydrogen supply tied only to the robustness of the power supply (assuming a secure water supply). In this suggestion, to sustain hydrogen production at any period for methanol, the electrolysis plant power would be 205 MW$_{AC,}$ and 24MW$_{AC}$ for syncrude/SAF.

Figure 3.4 demonstrates this coupling of arrangements. In this scheme, the definitions follow: 1) Water purification plant including feed pump and reservoir; 2) Transformer; 3) Rectifier; 4) PEM electrolysis stack; 5) Anode: Gas water separator; 6) Anode: Heat exchanger for O_2 cooling; 7) Water circulation pump; 8) Heat exchanger; 9) Ion exchanger; 10) Cathode: Gas water separator; 11) Cathode: Heat exchanger for H_2 cooling; 12) Deoxidizer; 13) Condensing heat exchanger; 14) Dryer; 15) Compression chiller; and 16) Dry cooler.

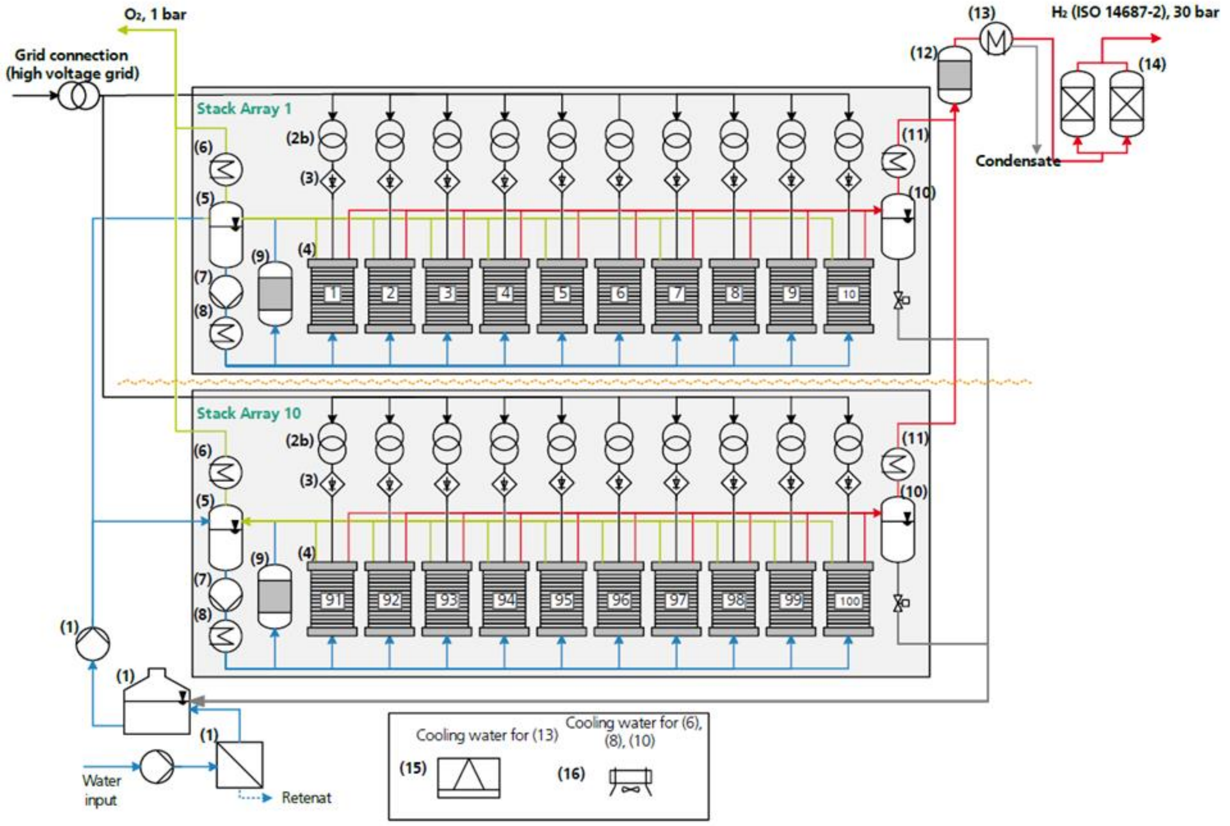

Figure 2-9 PEM-Stack arrays for large-scale electrolysis. Source: Fraunhofer (2022)

2.5.2 Water Supply

Based on the literature review and on two main electrolyzer manufacturers' technical datasheets, this scale of **electrolysis plant will demand ~34 tons/h of deionized water for the methanol plant and ~4 tons/h for syncrude/SAF scenario.** Most electrolyzer's manufacturers offer an integrated solution that include a water treatment station to bring tap water to deionized water within purity requirements for their stacks.

Within electrolysis plant, there are other sub-processes that require water with less treatment intensity, such as gas separation and cooling, for example. In this sense, methanol scenario demands extra 51 tons/h of tap water, while syncrude/SAF demands +6tons/h. As in the green fuel plants, a significant portion of this water can be recovered in later stages. Considering the worst scenario (no water recovery), **the total water consumption of the electrolysis plant is up to 10 tons/h for syncrude/SAF production and 85 tons/h for methanol**.

Regarding the green fuel plants, as previously indicated in Chapter 3 (also summarized in Table 4.1), facilities in the syncrude/SAF plant scenario require 43,3 tons/h of water, while the scenario for methanol production indicated a demand of 84 tons/h. Tap water quality is also sufficient. In this way, **a total of ~ 53,3 tons/h of treated water must be available to support syncrude/SAF production plant and ~169 tons/h to methanol**, including the green fuel facilities and electrolysis.

Although it may seem unnecessary to provide high-quality water for SMR as the water is expected to be converted to steam, some authors suggest that the reliable operation of the boilers used for steam generation requires very high-quality water (Shah, 2013). Therefore, both water streams, for electrolysis and synthetic fuel plants, will require high-quality treatment processes. In this sense, about 70% of water can be recovered from high-treatment processes

(SHAH, 2013), resulting in a total raw water withdrawal of ~74 tons/h for syncrude/SAF and ~237 tons/h for methanol, as shown in Figure 2.10.

A survey was conducted to determine the availability of water close to the location where the industrial complex is planned to be implemented. Figure 2.10 presents a map that shows the location of nearby current permits. Red numbering refers to surface water grants described, and black numbering refers to groundwater grants. Next, Table 2.10 provides information on the granted daily flows.

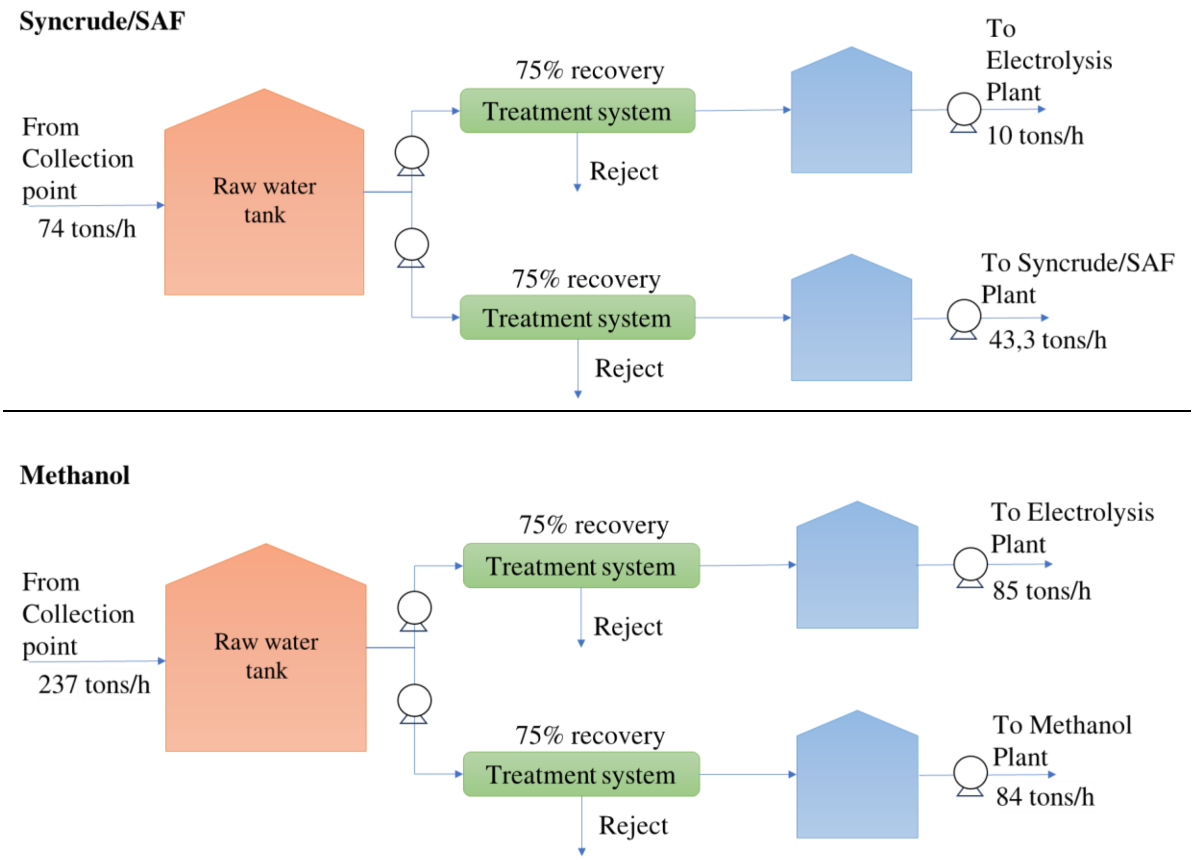

Figure 2-10 Water flowchart from collection to processes

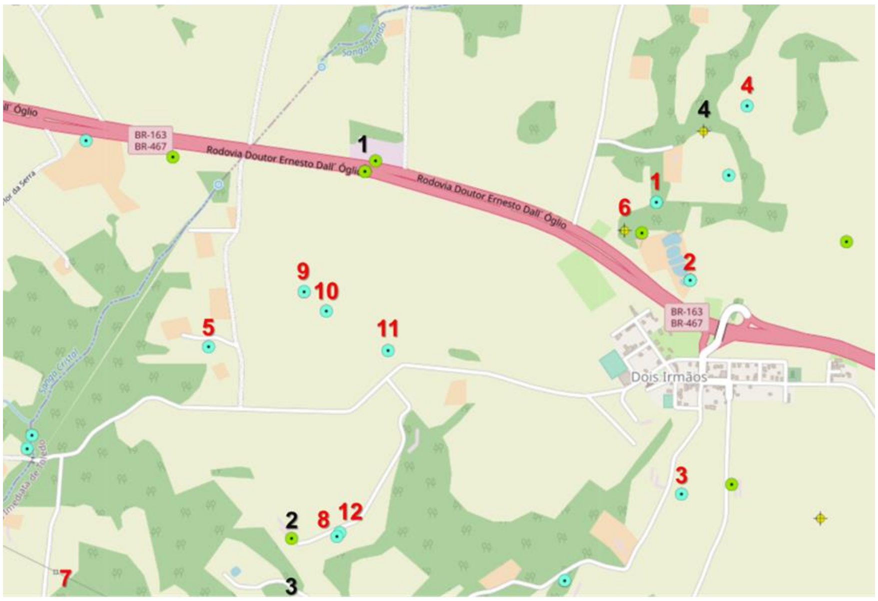

Figure 2-11 Location of water exploiting grants nearby. Source: IAT (2023).

Table 2-2 Water flow grants nearby the industrial complex. Source: SIGARH (2023).

ID	OWNER	GRANT (m^3 dia^{-1})	ACTIVITY	VALID UNTIL
SURFACE WATER				
1	Private owner	360	Fish farming in excavated ponds	25/10/2028
2	Private owner	240	Fish farming in excavated ponds	04/10/2028
3	Private owner	32,99	-	14/01/2025
4	Private owner	1,53	Dairy Cattle Farming	08/10/2023
5	Private owner	129,6	Fish farming	14/10/2025
6	SANEPAR* (Paraná State water company)	10 (240)	Water collection, treatment, and distribution	02/08/2025
7	Private owner	30	Pig farming	23/10/2023
8	Private owner	38	Pig farming	19/07/2024
9	Private owner	1,35	Dairy Cattle Farming	06/08/2024
10	Private owner	46,44	Fish farming	23/09/2023
11	Private owner	15	Fish farming in excavated ponds	08/05/2023
12	Private owner	46,77	Fish farming in excavated ponds	14/09/2024
UNDERGROUND WATER				
1	Agroindustry	3,1	-	22/12/2023
2	Private owner	26,3	Cattle/Pig Domestic use	02/08/2022
3	Private owner	43,2	Pig farming Domestic use	21/06/2024
4	SANEPAR (Paraná State water company)	até 306	Water collection, treatment and distribution	02/08/2025

Source: IAT (2023). *Granted flow m³ h-1 (max. m³ day-1)

When it comes to surface water, the largest grant in the region is managed by SANEPAR (Companhia Paranaense de Água e Saneamento). They are responsible for a daily flow of 10 m^3/h, which accounts for less than 10% of the total estimated demand for the H2UPPP project. As for groundwater, SANEPAR currently holds a permit of 12.75m^3/h near the site. It is evident from the data that there is low demand for both surface and underground water near the industrial site. An assessment was conducted to evaluate water availability in nearby bodies as follow:

- Arroio Guaçu:
    - Located north of the plant ~5,5 km straight line.
- $Q_{7,10}$=2,18m^3/s; $Q_{95\%}$=4,77m^3/s and Q_{mean}=13,76m^3/s
- Total water flow: ~17172m^3/h
    - Small hydropower plant PCH Moinho (Cercar) downstream
    - Sub-basin total available flow for collection: 1508,98 m^3/h
- Marreco River
    - Located southwest of the plant ~10 km straight line.
- $Q_{7,10}$=0,92m^3/s; $Q_{95\%}$=1,95m^3/s and Q_{mean}=5,52m^3/s)
- Total water flow: ~7020m^3/h
    - Aquaculture intensive production downstream and Suine activities upstream

- Sub-basin total available flow for collection: 605,74 m^3/h
- São Francisco River
- Located south of the plant ~11 km straight line.
- $Q_{7,10}$=6,88m^3/s; $Q_{95\%}$=15,29m^3/s and Q_{mean}=38,76m^3/s)
- Total water flow: ~55044m^3/h
- PCH São Francisco upstream
- Sub-basin total available flow for collection: 773,15 m^3/h

The Municipal Water Resources Plan of Toledo indicates that the ratio between the current flow captured and the available flow for the Arroio Guaçu and Rio Marreco sub-basins meets the minimum conditions for accepting new grants. However, the Rio São Francisco sub-basin has an index above 15% of the same ratio and is indicated with a yellow signal in relation to new concessions.

After analyzing the water demand of the H2UPPP project and surveying the water availability in the nearby region, it is recommended that an assessment be conducted to allow the exploitation of surface or underground water in the Arroio Guaçu sub-basin. This is because it has a greater flow available for capture and is closer in proximity, making it the ideal source to meet the project's water requirements.

As stated in Report 1, it has been suggested to investigate the potential benefits of constructing a large-scale photovoltaic solar plant in proximity to the synthetic fuel plant. Such a step could help to expand the useful catchment area and promote a more sustainable process overall.

After conducting a brief study with the Instituto Água e Terra, it was discovered that there are agro-industries within a 50-70km radius of the area being evaluated with water demands that exceed 400 m^3/h. Therefore, the proposed concession for a total flow of 237 m^3/h in the current project is not expected to face significant obstacles during the granting process. As part of the assessment, we also looked at how wastewater from agro-industries could be used and treated. However, transporting the wastewater over distances greater than 30km would require significant investments in piping and pumping. While it is a highly sustainable option, it is not recommended from a technical or financial perspective. In the future, it may be worth considering using these agro-industrial effluents to produce additional biogas if the project is expanded.

2.5.3 Power Supply

Firstly, to ensure compliance with international certification and the RED II directives (which will soon be revised in RED III), it's important to clarify certain definitions related to power supply for the industrial complex.

- Advanced biofuels: biofuels that are produced from the feedstock listed in RED III Part A of Annex IX (within H2UPPP scenario, applied to letter f - Animal manure and sewage sludge);
- Renewable fuels of non-biological origin (RFNBO): liquid and gaseous transport fuels which the energy content is derived from renewable sources other than biomass (e.g., using H_2 produced from electrolysis powered by renewables, known as green hydrogen).

Products synthesized within the H2UPPP project are obtained through thermo-chemical processes using animal manure's biogas as feedstock in addition to green hydrogen (besides heat and water). Therefore, even integrating green hydrogen into product manufacturing does not lead to an RFNBO classification. Thus, one could assume that H2UPPP synthetic products are more likely to aim at accomplishing the RED III Advanced Biofuel criteria.
Assuming this classification, it is essential to prioritize the lowest possible carbon footprint from the certification of the synthesized products by considering the impact of each stage of the production process. Therefore, it is suggested to size the energy supply of the electrolyzers in a way that meets the criteria for sustainability, greenhouse gas emissions reduction, and compliance with the criteria defined for RFNBO as well. This way, the market will receive a product with a high level of sustainability that meets all the necessary criteria.
For the RFNBO criteria to be met, the following principles must be considered:

- Renewability: Requirement for the renewable share of electricity as a production input.
- Additionality: Use only additional installed capacity to produce RFNBOs. Furthermore, RED III defines additionality by the absence of subsidies received.
- Geographical correlation: Defines a geographical area in which the power plant and the electrolyzer must be located.
- Temporal correlation: Describes the time difference between electricity and RFNBO production.

RED III accounts for one case related to a direct connection and four alternative cases that are related to an indirect connection:
(1) Direct connection including additionality criterion, or
(2) Four alternative cases for an indirect connection (via the grid):

a) Renewable share in the same bidding zone of the grid of at least 90%, or
b) Emission intensity of max. 18 gCO_{2eq}/MJ in the electricity grid mix, or
c) Electrolyser serves to prevent grid congestion, or
d) PPA(s) based on additional electricity capacities.

In large-scale projects like H2UPPP, adopting only direct connection schemes between sources and electrolyzers would require investments in hundreds-of-MW capacity power grids and substations in order to support energy security for the green hydrogen production plant, increasing both the CAPEX and implementation schedule. In this sense, it would be more effective to explore flexible solutions that include the 4 possible indirect connection options.

As for alternative 2a, the South Region has a large capacity to generate electrical energy from the most diverse sources. According to data from the National Electric System Operator (ONS, 2023), the southern subsystem of the country contributed, in the year 2022, to the generation of more than 95,000 GWh, considering the categories of hydro (82.1%), thermal (11.4%), and wind (6.4%). For thermal energy, it is considered the generation coming from renewable sources (biomass and agro-industrial waste) and non-renewable sources (coal, gas, fuel oil, diesel oil, and petroleum). Based on this, it is observed for the year in question a generation of 92% coming from renewable sources, with the category primarily represented by hydroelectric projects. Table 3.3 below brings together the main data relating to electrical energy generation in the southern subsystem, highlighting its main generating sources. To highlight the large renewable share, Figure 3.7 demonstrates the evolution of the share of renewable and non-renewable energy in the electrical matrix of the Southern subsystem.

So, if we consider the bidding zone where the synthetic fuel plant is located as the South submarket of the Brazilian electrical system, data suggest that the 90% renewable share target was met from 2016 to 2019, and again in 2022. This scenario is very positive for the States in the southern region of Brazil, making it attractive for projects whose main purpose is the production of RFNBO. However, it is important to keep in mind that there is no way to guarantee that the share of renewables will be sustained in subsequent years, which could imply future insecurity regarding the certification of exported products. Additionally, there are still doubts about the definition of a bidding zone within the Brazilian electric sector.

Table 2-3 Southern Brazilian submarket generation share

Year	Total Gen	Hydro	Termo (renewable)	Termo (non-renewable)	Wind	Renew.	Non-renew.
	GWh					%	
2013	90.959	77.673	11	12.150	1.125	87	13
2014	102.352	87.341	19	12.966	2.026	87	13
2015	111.614	94.307	1.180	12.293	3.834	89	11
2016	107.456	92.736	2.215	7.548	4.957	93	7
2017	88.514	72.212	2.815	7.489	5.998	92	8
2018	86.864	70.911	3.002	7.085	5.866	92	8
2019	86.444	69.995	3.118	7.588	5.743	91	9
2020	60.900	41.839	3.103	9.474	6.484	84	16
2021	75.031	52.874	3.097	12.763	6.297	83	17
2022	95.222	78.186	3.374	7.515	6.075	92	8

Source: ONS (2023).

To meet the requirements of alternative 2b, it is necessary to have Brazilian and/or international accredited PoS (Proof of Sustainability) that allows for certified accounting of the emission intensity of the energy mix used in the bidding zone. However, due to the presence of gas and coal thermoelectric plants in the Southern subsystem, it is expected that the recorded emissions will exceed the maximum criteria required. Besides, standards in this regard are still necessary.

Regarding alternative 2c, a vast study on transmission grid congestion in the Southern subsystem would be necessary for sizing Electrolysers to operate in a "system-friendly" mode, indicating specific connection buses where this equipment could really help to improve the grid stability. This study should be provided by utilities jointly with the National Grid Operator (ONS).

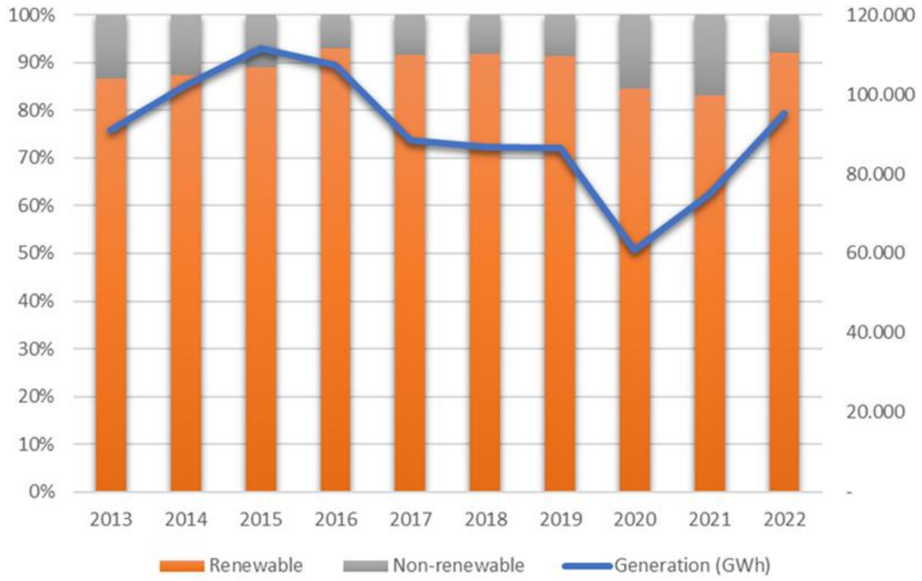

Figure 2-12 Share of renewable and non-renewable energy in the Southern submarket Electricity Generation. Source: ONS (2023).

After analyzing the challenges that were highlighted in the previous alternatives, PPA(s) based on additional electricity capacities are the most recommended ones (alternative 2d). However, it's important to uphold the principles of renewability, additionality, temporal, and geographic correlation. To achieve this, it is recommended to sign Power Purchase Agreements (PPAs) with new renewable plants that meet the geographic correlation criterion. Smart metering systems should be implemented in nearby (alternative 1) and distant (alternative 2d) plants to manage the correlation between electrolyzer generation and consumption on an hourly basis. Real-time smart metering must regulate electrolyzers consumption to meet both, local and remote renewable plants. If the sum of local and remote renewable energy exceeds the electrolyzer's capacity, the excess power could be sold in the Electricity Free Market. If the sum of local and remote renewable energy production is lower than the capacity of the electrolyzer, the smart meter regulators should decrease the intensity (consumption) of electrolysis. For additional information, the average price charged by energy generators on the Free Market classified as incentivized generation (renewable) in the long-term market (Year+1 to Year+4) ranged R$110 to R$172 per MWh (21 to 33 €/MWh) between October/2022 and October/2023. The same type of incentivized generation in the short-term market (Month+1 to Month+3) fluctuated in the same period between R$88 and R$112 per MWh (17 to 21 €/MWh) (Dashboard Dcide, 2023).

To enhance operational security, it is advisable to adopt a flexible connection scheme (Figure 3.8). This would involve building new renewable generation plants that are directly linked to the industrial complex. The scheme should also enable the complex to be connected to the grid, allowing for the import of energy via Power Purchase Agreement (PPA) from the generation plant located in areas that offer better conditions for renewable energy production.

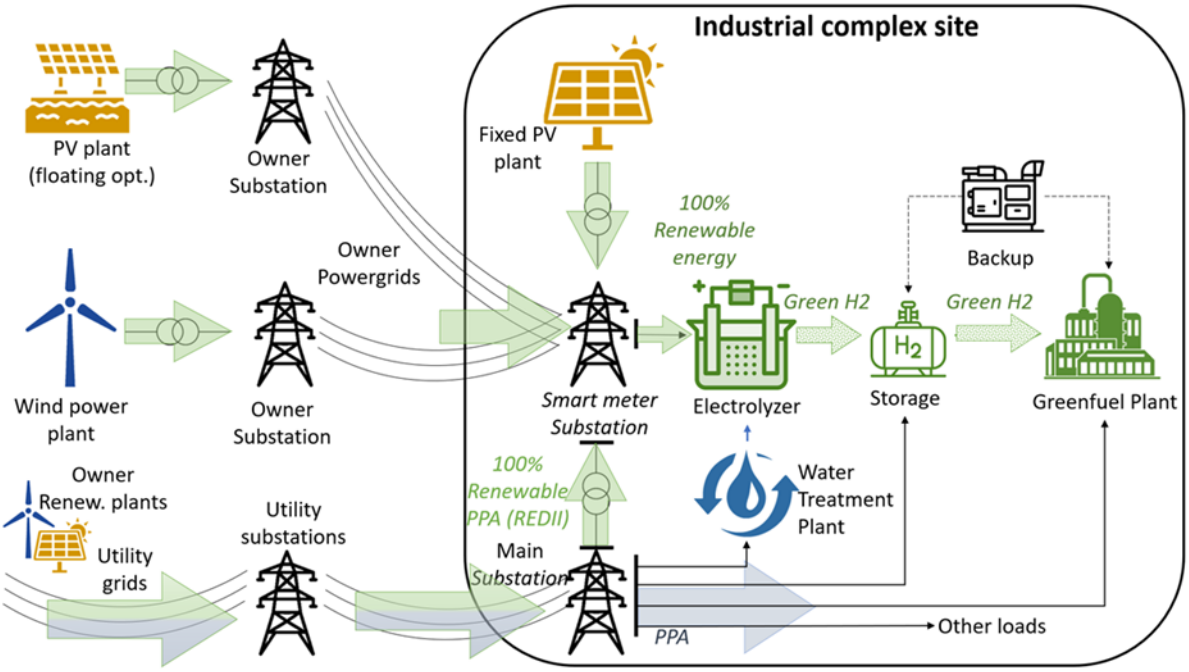

Figure 2-13 Standard power supply scheme for both direct and indirect connection alternatives.

As a result, alternative 1 and alternative 2d could be complementary, depending on the availability of generation and grid capacity. In this scenario, we need to assess the remaining load of the nearest 138kV substation to the site, which is the Vila Gaúcha Substation located at a distance of approximately 20km. The objective is to minimize the investment in transmission grids and transformers. If there is no available capacity in the nearest 138kV substations, we would need to invest in connecting the site via 230kV substations with sufficient remaining capacity, as already evaluated in Report 1. The Guaíra 230kV Substation, which has 950MW remaining, is located ~64.3km from the site while the Cascavel 230kV Substation, which has 700MW remaining, is located ~63.8km from the site.

An estimate was made of the total substation capacity required to serve the plants. For the electrolysis plant, a demand of 192MW_{AC} was considered, which already included BoP of 3kWh/kg and an estimated consumption of 0.64kWh/kg for a compression system from 30bar (electrolyzer output) to 103bar (storage) (IRENA, 2020). Additionally, in Chapter 3, a demand close to 4MW_{AC} was estimated for the synthetic fuel plant, which brings the total installed capacity to approximately 196MWAC. Therefore, a substation capacity close to 250MVA would be sufficient to meet the total demand, considering a power factor greater than 0.92 (as per ANEEL requirement) and a service factor of around 1.2.

To ensure the optimal functioning of the substation, it is recommended that it be served by at least two transformers of equal capacity operating in parallel. Additionally, it is important to assess the need for equipment installation that can minimize the impact of the plant on the grid while meeting the utility's requirements. Some of the equipment that may be required for this purpose includes harmonic filters, SVC compensators (static var compensators), STATCOM compensators (static synchronous compensators), series reactors, and capacitor banks. This assessment is necessary given that the primary demand for the substation comes from the rectifiers that will feed and control the electrolyzers. These rectifiers are based on power electronics technologies which generally harm the energy quality of the grid they are connected to.

If the same substation is going to be used for connecting renewable generation plants to meet alternative (1), it needs to have the capacity to handle the flow of peak power from the renewable plants. In this case, it is recommended to have a total substation capacity of around 500MVA, regarding the next topic estimates. However, a study should be carried out to determine which option is more viable: connecting the renewable plants directly to the industrial complex's substation or connecting them to the nearest technically viable utility substation. The latter option would only consider alternative 2d within the scope of REDII.

2.5.4 Solar and Wind Power Plants

Considering the recommendations in the previous subsection, a preliminary sizing of a photovoltaic plant and a wind plant was carried out, taking into account meeting the total demand of the industrial complex. The System Model Advisory (SAM) was used to assist the simulations (NREL, 2023).

The parameters considered for the preliminary sizing of the solar plant were:

- Historical TMY 2007-2021 data from Marechal Candido Rondon weather station (Reference: Climate One Building, 2023)
- 550Wp comercial PV modules
- 200 x 1MW comercial inverters for methanol scenario;
- 140 x 250kW commercial inverters for syncrude/SAF scenario;
- 10% of DC/AC oversizing
- 215MWp of PV-modules installed, ground-fixed with inclination-angle equals latitude, north face azimuth, and ground-covered ratio of 0.3.

For the wind plant pre-sizing, the following parameters were considered:

- Average wind speed (m/s): 8.2 (as reported for Micro-region 1 in Report 1)
- Reference height for wind speed (m): 100
- Fator k Weibull: 2
- Turbulence coeficient: 0.14
- 50 turbines, model ATB NREL Reference 4MW for methanol scenario;
- 9 turbines, model ATB NREL Reference 4MW for methanol scenario;

The main results are summarized in Table 2.4 and Table 2.5:

Table 2-4 Results related to RE plants for syncrude/SAF scenario power supply.

SYNCRUDE/SAF	Power (MW)	Energy (GWh/y)	RE share
Solar-PV	35	72,45	37%
Wind farms	36	140,3	72%
Total Gen.	71	212,75	109%
Power Substation	85		

Table 2-5 Results related to RE plants for methanol scenario power supply.

METHANOL	Power (MW)	Energy (GWh/y)	RE share
Solar-PV	200	362	21%
Wind farms	200	780	46%
Self-production PPA (hydro/biogas)	80	560,64	33%
Total Gen.	480	1702,64	102%

In methanol scenario, adding the estimated capacity of equivalent full hours of both, solar and wind plants, we have approximately 5700 hours per year. Even considering approximately 760 hours per year of stops for preventive/corrective maintenance, the operational regime of the industrial complex would be met in only 67% of the available operational period. However, the option to increase the installed capacity of renewable plants would greatly increase the amount of energy in excess of the plant's demand, resulting in losses.

As a way of supplementing the remaining renewable energy demanded for the plant, it would be advisable to close PPA contracts with hydroelectric plants or even biogas or biomass thermoelectric plants, which would guarantee a supply of base energy (firm energy). These plants can reach capacity factors close to 80%, which would yield an additional production of ~560GWh/year, considering full hours to meet the complete energy demand (FERNANDES et al., 2021).

Concluding, the CAPEX and OPEX for the whole green hydrogen related plants (electrolysis, water collection and treatment, power station and renewable plants) is described in Table 2.6 for syncrude/SAF scenario (process A) and Table 2.7 for methanol.

Table 2-6 CAPEX and OPEX related to green hydrogen production for syncrude/SAF.

SYNCRUDE/SAF	Power (MW)	CAPEX	OPEX (O&M)	OPEX (electricity)	OPEX (water+treat.)	OPEX (total)
Solar-PV	35	$ 44.086.000,00	$ 525.000,00	$ 224.000,00	$ -	$ 749.000,00
Wind farms	36	$ 50.400.000,00	$ 900.000,00	$ 230.400,00	$ -	$ 1.130.400,00
Total Gen.	**71**	**$ 94.486.000,00**	**$ 1.425.000,00**	**$ 454.400,00**	**$ -**	**$ 1.879.400,00**
Electrolysis	24	$ 23.396.000,00	$ 480.000,00	$ 9.309.576,00	$ 500.000,00	$ 10.289.576,00
Compressors	9			$ 3.491.091,00		$ 3.491.091,00
Power Substation	85	$ 9.463.562,75	$ 189.271,26	$ -	$ -	$ 189.271,26
TOTAL		$127.345.562,75	$ 2.094.271,26	$ 13.255.067,00	$ 500.000,00	$ 15.849.338,26

Table 2-7 CAPEX and OPEX related to green hydrogen production for methanol.

METHANOL	Power (MW)	CAPEX	OPEX (O&M)	OPEX (electricity)	OPEX (water+treat.)	OPEX (total)
Solar-PV	200	$251.920.000,00	$ 3.000.000,00	$ 1.280.000,00	$ -	$ 4.280.000,00
Wind farms	200	$280.000.000,00	$ 5.000.000,00	$ 1.280.000,00	$ -	$ 6.280.000,00
Self-production PPA	80	$ 120.000.000,00	$ 8.000.000,00	$ 512.000,00	$ -	$ 8.512.000,00
Total Gen.	**480**	**$651.920.000,00**	**$ 16.000.000,00**	**$ 3.072.000,00**	**$ -**	**$ 19.072.000,00**
Electrolysis	205	$151.187.000,00	$ 4.100.000,00	$ 79.519.295,00	$ 1.250.000,00	$ 84.869.295,00
Compressors	45	$ 30.000.000,00		$ 17.455.455,00		$ 17.455.455,00
Power Substation	550	$ 61.234.817,81	$ 1.224.696,36	$ -	$ -	$ 1.224.696,36
TOTAL		$ 894.341.817,81	$ 21.324.696,36	$ 100.046.750,00	$ 1.250.000,00	$ 122.621.446,36

2.5.4.1 Solar-PV CAPEX/OPEX survey

Costa (2023) assessed strategies for marketing the production of photovoltaic generation systems. In their study, the CAPEX and OPEX were determined for a 250 MWp (199.8 MWac) photovoltaic plant installed in the inland of the state of Ceará. In this study, the CAPEX calculations integrated all expenses related to the acquisition of equipment (modules, inverters, low-voltage cables, and trackers), network connection infrastructure (voltage step-up substation, high-voltage cables, substation connection bay), as well as labour costs associated with the construction of the solar park. In the OPEX calculations, the following were considered: transmission system usage tariff (TUST), plant operation and maintenance costs, land lease, asset management, and electricity service inspection fee (TFSEE). Table 2.8 summarizes the financial analyses of the future project.

Table 2-8 Summary of photovoltaic system (250 MWp) CAPEX and OPEX

Physical System Configuration	Value		Unit.
Trackers	1998		un.
Modules per tracker	54		un.
Table-to-table distance	6,5		m
Module power	570		Wp
Modules per inversor	486		un.
Inversor (Total)	222		un.
Modules (Total)	107892		un.
Total Module Power (peak)	250.3		MWp
Total inverter power	199.8		Mwac
CAPEX	$/Wp		Total Costs ($)
Inverter	0.049		12,160,785.43
Photovoltaic Module	0.176		44,194,321.03
Trackers	0.111		27,868,472.67
Logistics	0.008		2,015,650.18
Specialist PV	0.152		38,002,454.45
Specialist HV	0.081		20,267,975.71
Environmental Compensation	0.004		891,790.93
Expenses ESG	0.002		506,699.39
TOTAL	0.58		145,908,149.80
OPEX	Annual value ($)	Percentage (%)	$/Wp
TUSDg 230,0 kV (R$6,50/kW)	$ 328.947,37	16%	0,0013
O&M (20.000 R$/MWp/year)	$1.012.145,75	48%	0,0040
Land Lease	$ 265.635,77	13%	0,0011
Asset Management (7,000 R$/MWp/year)	$ 354.251,01	17%	0,0014
Aneel (TFSEE)	$ 153.315,36	7%	0,0006
TOTAL	$2.114.295,26	100%	0,0085
$=R$4.94. Source: Costa (2023).			

For comparison purposes, SOUZA (2022) conducted an economic analysis for the installation of a photovoltaic mini-generation system (756 kWp) to supply a leachate treatment unit in landfills. The CAPEX considered equipment costs (inverters, panels, structure, cabling, protection devices, etc.), civil work for plant construction, logistics, grid connection, engineering costs, commissioning, among others. The land lease was not taken into account as the facility had available land area for the project installation. Regarding OPEX, it considered preventive equipment maintenance, occasional component replacements, and personnel responsible for monitoring the plant. Table 2.9 summarizes the financial analyses of the future project.

Table 2-9 Summary of photovoltaic system (756 kWp) CAPEX and OPEX.

CAPEX				
Costs	Quant.	Unit. Cost ($)	Total Cost ($)	$/Wp
Photovoltaic Module	1400	260.93	365,303.64	0.48
Inversor	5	6,910.11	34,550.56	0.05
Structure	350	153.04	53,562.75	0.07
Workforce	1	97,165.99	97,165.99	0.13
Civil work	1	111,336.03	111,336.03	0.15
Installation costs	1	60,728.74	60,728.74	0.08
Equipment/materials	1	30,364.37	30,364.37	0.04
TOTAL			753,012.10	1.00
OPEX				
Annual costs			Total Cost ($)	$/Wp
Labor for operation			77,732.79	0.10
Maintenance costs			4,048.58	0.01
Total costs			81,781.38	0.11
$=R$4.94. Source: SOUZA (2022).				

Dias and Nieto (2021) also conducted an economic assessment aiming to determine the feasibility of a 5 MWp plant. CAPEX included equipment and materials comprising the project, engineering analyses, project execution, and grid interconnection. For OPEX, they took into account the system's lifespan (25 years), monetary adjustments (IPCA), land leasing costs, security, maintenance, and operation expenses. Table 3.10 summarizes the financial analyses of the future project.

Table 2-10 Summary of photovoltaic system (5 MWp) CAPEX and OPEX

CAPEX			
1	Engineering		
1.1	Environmental analysis	1,113.36	0.000
1.2	Geological analysis	222.67	0.000
1.3	Topographic analysis	-	-
1.4	Executive Project	132,801.62	0.027
1.5	Owner's Engineering	106,241.30	0.021
Total		240,378.95	0.048
2	Main equipment		
2.1	Photovoltaic Module	2,197,174.74	0.439
2.2	Inversor	385,786.92	0.077
2.3	Monitoring	15,587.04	0.003
Total		2,338,693.83	0.468
3	Other equipment		
3.1	Junction box, Cubicles, Wiring, Connectors, Structures, String boxes, Measurement system, Cleaning system, Transformer, Solarimetric station	865,343.61	0.173
Total		865,343.61	0.173
4	Other services		
4.1	Commissioning	66,400.81	0.013
4.2	Logistics	96,120.52	0.019
4.3	Civil Work, Assembly and Civil ART	819,878.54	0.164
Total		982,400.48	0.196

5	Transmission and Conexion		
5.1	Transmission Line	133,603.24	0.027
5.2	Inbound bay	111,336.03	0.022
Total		**244,939.27**	**0.049**
6	Other		
5.1	Travels	7,793.52	0.002
5.2	Local expenses	7,793.52	0.002
Total		**15,587.04**	**0.003**
TOTAL CAPEX		4,687,343.18	0.94
OPEX (year 1)			
Item		Total	$/Wp
1	Annual land lease	13,360.32	0.003
2	Annual insurance	-	-
3	Annual O&M	26,560,32	0.005
4	Annual security	11,133.60	0.002
5	Inverter replacement*	-	-
6	Other plant demands	293,927.13	0.059
TOTAL OPEX		**344,981.38**	**0.07**
*$3,116,214,92 in year 8; $=R$4.94. Source: DIAS and NIETO (2021).			

2.5.4.2 Wind power CAPEX/OPEX survey

Table 2.10 provides an overview of studies that conducted economic assessments for installing and operating onshore wind systems. Based on information from the International Renewable Energy Agency (IRENA, 2023), the global average for 2022 stood at 1,274 $ kW^{-1}. It's worth noting that countries like China, India, Sweden, and the United States have installation costs lower than the global average. In the case of Brazil, the total installation cost for systems averaged 1,052 $ kW^{-1}, a value considered for comparison.

Table 2-11 Summary of Wind Onshore CAPEX and OPEX.

CAPEX			
Reference	$ kW^{-1}	36 MW	200 MW
STEHLY et al. (2019)	1.426,00	51.336.000,00	285.200.000,00
EPE (2021)	910,93	32.793.522,27	182.186.234,82
IRENA (2023)	1.052,00	37.872.000,00	210.400.000,00
AQUILA et al. (2021)	1.600,00	57.600.000,00	320.000.000,00
EPE (2023)	1.200,00	43.200.000,00	240.000.000,00
OPEX			
Reference	$ kW^{-1}	36 MW	200 MW
STEHLY et al. (2019)	43,00	1.548.000,00	8.600.000,00
AQUILA et al. (2021)	32,00	1.152.000,00	6.400.000,00
IRENA (2023)	25,00	900.000,00	$5.000.000,00
EPE (2023)	18,22	655.920,00	3.644.000,00
*Real to dollar conversion (4,94 R$/$).			

2.5.4.3 Water Treatment CAPEX/OPEX survey

Figure 2.14 illustrates a flowchart of a surface water treatment and distribution system. Unlike surface waters, groundwater sources typically do not require undergoing conventional treatment, requiring only simple disinfection with chlorine when destined for human consumption. If the industrial process using this water is considered, in certain processes, not even disinfection would be necessary.

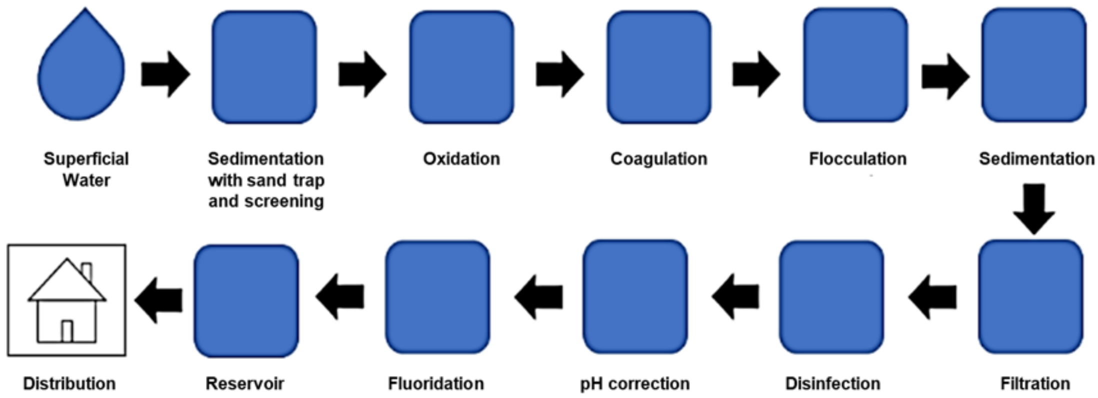

Figure 2-14 Flowchart of the surface water distribution system. Source: Ribeiro and Melo, 2020.

Regarding the CAPEX of Water Treatment Plants, back in 2007, Fernandez and collaborators made estimates on the implementation, operation, and maintenance costs of pumping and water treatment units. After an intensive survey of sizing parameters, the authors developed the following cost estimation curve for implementing WTPs:

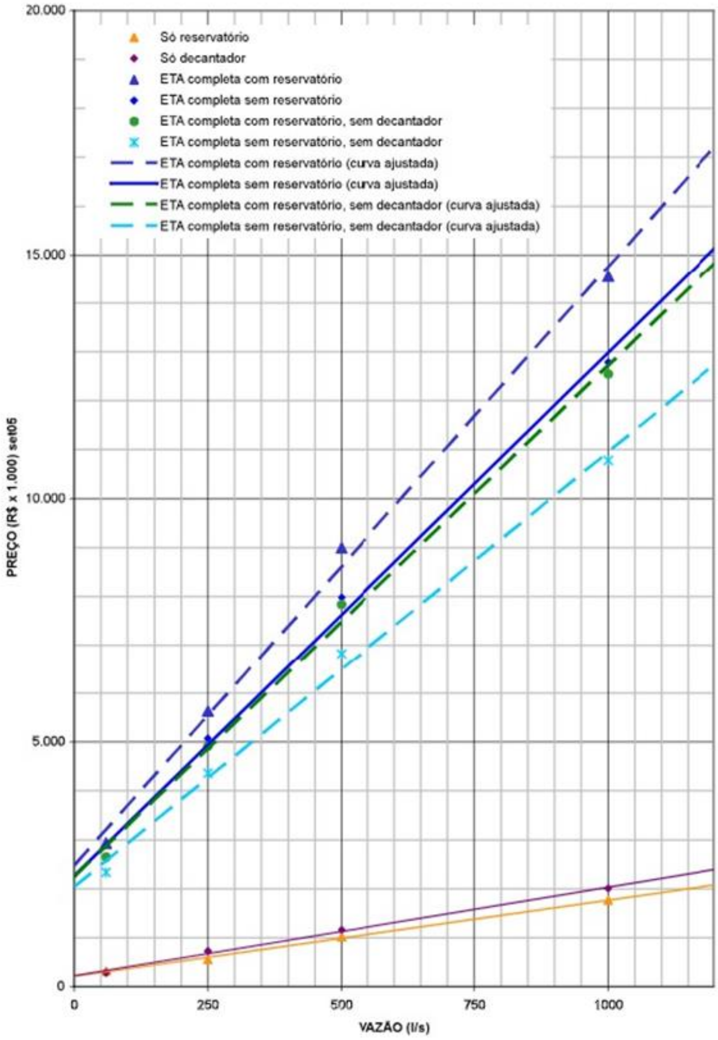

Figure 2-15 Curve for estimating implementation costs of WTPs.

In Figure 2.15, it's observed that for smaller-sized WTPs (flow rates up to 180 m^3 h-1), the CAPEX values ranged between 400-600 thousand dollars (2-3 million reais, considering the exchange rate of 4.94 R$/US$). Despite the study being almost 20 years old, approximate values are verified for similar-sized projects in recent years. For example, in bidding No. 073/2023 from the municipality of Apiacás, Mato Grosso, Brazil, the assessment for the construction of a water treatment plant designed for treating 108 m^3 h^{-1} is around 546.5 thousand dollars (2.7 million reais).

Furthermore, NeoWater company (2023) states that the investment varies considerably based on the desired volume and quality. In this regard, the average price of a WTP can range from $4,000-10,000 (R$20,000-50,000) for supplying 1000 m^3 of potable water per month. If extrapolated for a supply of 36,000 m^3 per month (50 m^3 h^{-1}), values of up to $365,000 (1,800,000 reais) can be considered.

Paranhos and Zanella (2023) conducted an economic assessment of potential water treatment and capture systems for industries located in the state of Rio de Janeiro. CAPEX and OPEX assessments were used as a reference. Table 2.12 summarizes their results.

Table 2-12 CAPEX and OPEX of the water treatment system for supply.

CAPEX 1000 m³ h⁻¹		Unit
Equipment	2,137,695.14	$
Civil	675,595.14	
Piping and Valves	342,031.17	
Electrical, Instrumentation, and Control	641,308.50	
Electromechanical Assembly	780,258.70	
Commissioning, Pre-operation, and Technical Assistance	80,161.94	
Engineering and Coordination	465,705.06	
TOTAL	5,122,755.67	
OPEX 1000 m³ h⁻¹		Unit
Energy	0.028	$/m³
Sludge Disposal	0.251	
Chemical Products	0.243	
Centrifuge	0.001	
General Maintenance	0.008	
Operational Team	0.047	
Monitoring Analyses	0.022	
TOTAL	0.599	
Dollar: R$4,94. Source: Paranhos e Zanella (2023).		

Regarding the OPEX of WTP projects, Ribeiro and Melo (2020) assessed the operation and maintenance cost of a water treatment system intended for human consumption in small towns. Considering expenses for correcting water characteristics, specialized labor, and energy costs, the authors arrived at values of $0.88 (R$4.33 per m^3) to superficial water and $0.09 (R$0.46 per m^3) for groundwater. It is worth noting that these values can vary depending on water quality and final use. This analysis considered treatment of around 40 $m^3 h^{-1}$.

Francisco and Arica (2018) also conducted a cost analysis applied to water treatment in a municipality in Rio de Janeiro. The authors considered conventional treatment, comprising the stages of coagulation, flocculation, sedimentation, filtration, disinfection, fluoridation, and pH correction. Additionally, they evaluated a non-conventional treatment excluding the disinfection and fluoridation stages. It's worth noting that the costs considered were solely related to the chemicals used in the treatment, reaching the value of $0.003 (R$0.014 per m^3) for conventional treatment and $0.0002 (R$0.0010 per m^3) for non-conventional treatment.

Based on the data presented in these studies, a CAPEX and OPEX were estimated for two scenarios (Table 2.13).

Table 2-13 CAPEX and OPEX estimates for assessed scenarios regarding WTP.

Scenario 1 - 74 m³ h⁻¹	
CAPEX	
Reference	$
Fernandez et al. (2007)	748,987.85
NeoWater (2023)	323,562.75

Paranhos e Zanella (2023)	379,083.91
Prefeitura de Apiacás (2023)	374,493.93
OPEX	
Reference	$ month^{-1}
Ribeiro e Melo (2020)	46,700.90
Paranhos e Zanella (2023)	31,903.29
Scenario 2 - 237 m^3 h^{-1}	
CAPEX	
Reference	$
Fernandez et al. (2007)	1,949,013.16
NeoWater (2023)	1,036,275.32
Paranhos e Zanella (2023)	1,214,093.08
Prefeitura de Apiacás (2023)	1,199,392.71
OPEX	
Reference	$ month^{-1}
Ribeiro e Melo (2020)	149,569.07
Paranhos e Zanella (2023)	102,176.74
Dollar: R$4,94.	

For comparison purposes, Table 2.14 gathers information on water intake permits (groundwater and surface) from an Agro-industrial Cooperative located near the region where the plant could potentially be installed.

Table 2-14 Permits for groundwater/surface water extraction issued to an Agroindustrial Cooperative in Western Paraná

Statute	Extraction Volume (m^3 h^{-1})*	Validity	Source type	Source
25254/2023	145	aug/19	Surface	Rio Santa Fé
25108/2023	478	aug/29	Surface	Rio São Camilo
11187/2023	9	jan/29	Groundwater	Aq. Serra Geral
10015/2023	9	jan/29	Groundwater	Aq. Serra Geral
11124/2023	37	jan/29	Groundwater	Aq. Serra Geral
11179/2023	40	jan/29	Groundwater	Aq. Serra Geral
11128/2023	24	jan/29	Groundwater	Aq. Serra Geral
* Maximum allowed flow rate. Source: IAT (2023).				

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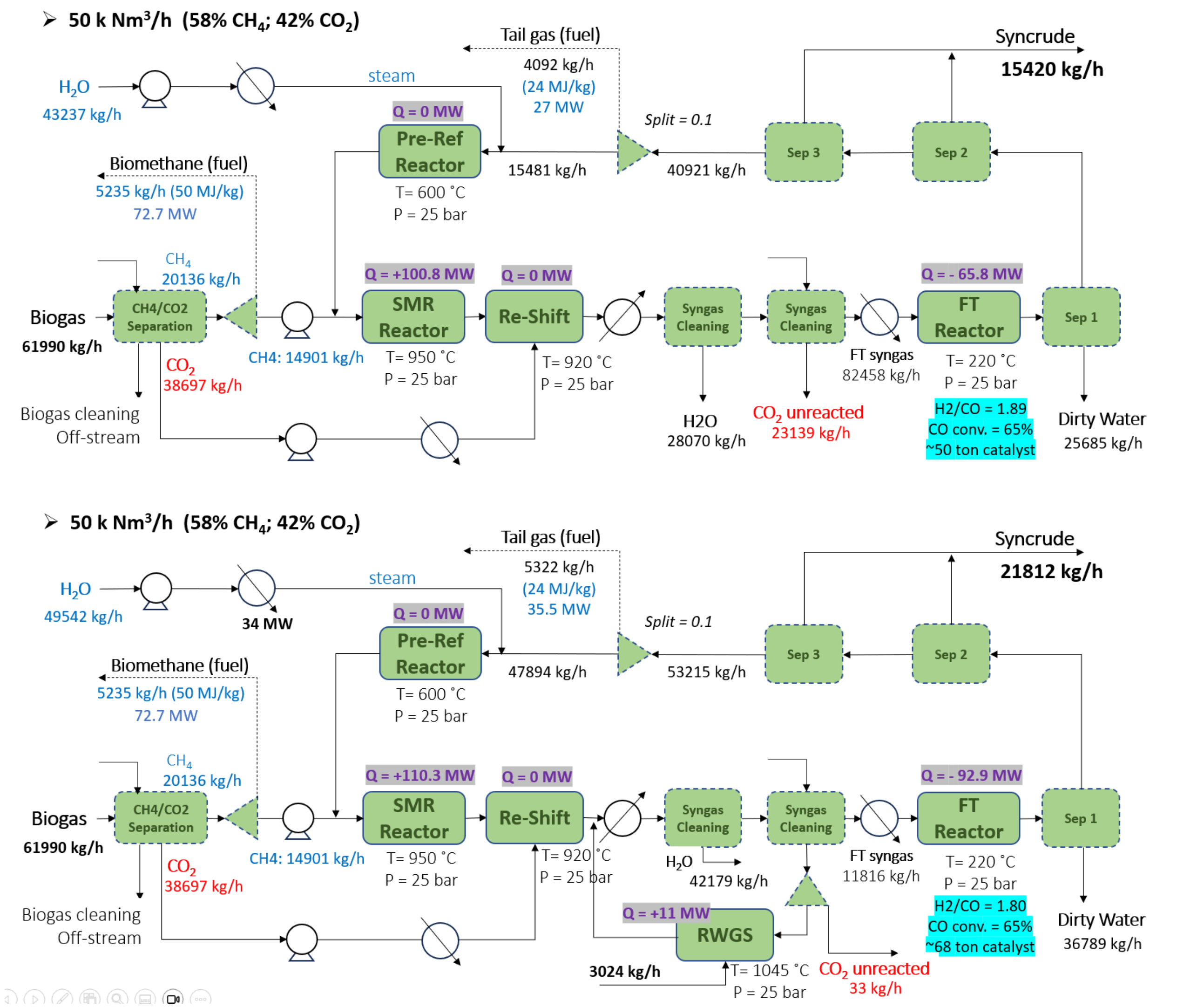
2.7 Economic Analysis

An overview of simple business cases for the various process layouts, presented in Chapter 2, is carried out in this Chapter. The baseline for this study was excluded from the subsequent analysis due to its inferior performance compared to the other scenarios. Instead of the first proposal presented in Chapter 2, without recycling, an alternative process for methanol production from syngas has been proposed. The following Figure 2.16 presents the process layouts together and summarize final product (syncrude or methanol) yield in mass per h terms. In addition, the following table, Table 2.15, summarizes the process layouts yields.



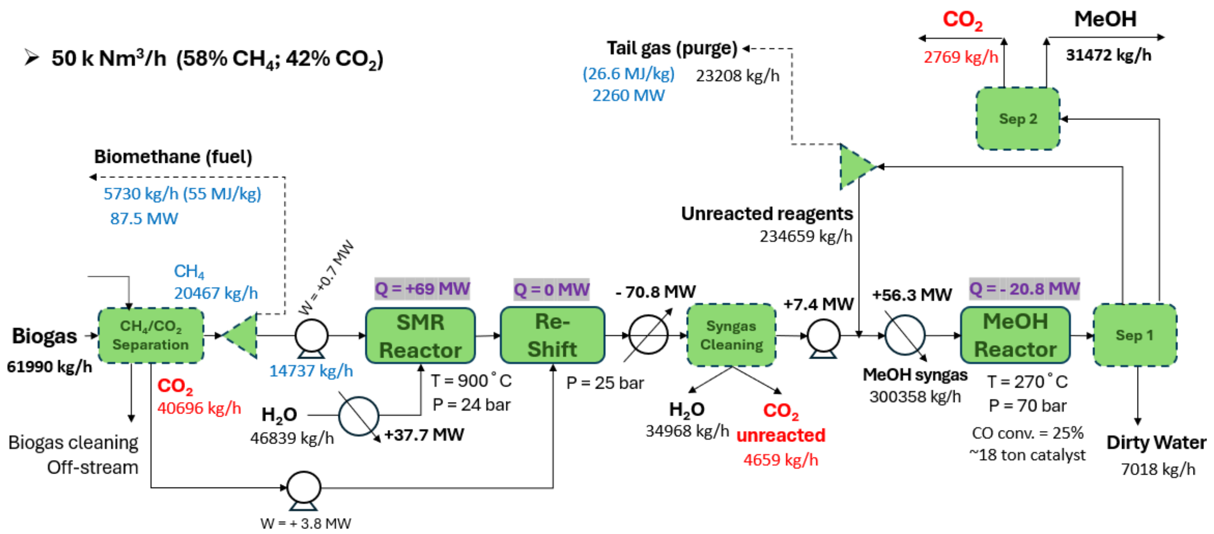


Figure 2-16 Block flow diagrams for the base case process evaluated – biogas conversion to syncrude (a and b) and methanol (c).

Table 2-15 Summary of the process layouts yields.

Scenarios	Product Yield	Green H_2 requirement
Process Scenario A: Syncrude	15420 kg/h (syncrude)	639 kg/h (for Hydrocracker)
Process Scenario B: Syncrude	21812 kg/h (syncrude)	3419 kg/h (for rWGS & Hydrocracker)
Process Scenario C: Methanol (from Syngas)	31472 kg/h (methanol)	3427 kg/h (for correct syngas composition)

The proposed methanol synthesis process utilizes reactor units analogous to those employed in other syncrude processes and thereby efficiently harnesses the hydrogen stored in biomethane. Furthermore, it achieves an impressive methanol yield by effectively employing all the available CO_2, necessitating a relatively high hydrogen input of 3427 kg/h. Through precise calibration of the electrolyzer capacity and CO_2 utilization, the process can be further optimized, allowing for tuning of electrolyzer sizing and the option to vent a portion of the CO_2.

A simple business case analysis is carried out in Figure 4.2 offering an economical comparison of the different processes. In order to compare to actual market price, it is hypothesized that all the syncrude is hydrocracked to SAF, for which a market price is more easily identifiable. The additional process step is considered in the CAPEX estimation.

CAPEX is estimated using quotations from comparable processes as references. Specifically, the works of Spallina et al. (2016), Katebah et al. (2022), and DOE/NETL (2011) were consulted. Those articles provide a precise price information for relevant equipment, such as reformer, methanol reactors, FT reactors and other key components present in the process layouts. The costs of erected equipment found in the literature are then adjusted using exponential scaling law for the correct material flow rate in the proposed processes layouts (exponents of the scaling law are also reported in the literature). Finally, the total cost is updated to current prices using the CEPCI index values.

OPEX is calculated solely by the consumption of electrical utilities, compressors, pumps, and electrolizers. Consequently, it is consistently different between the three process scenarios considered, mostly depending on the electrolizers capacity required and the reactor operating pressure (methanol reactor requires higher pressures). The electricity price has been hypothesized to be 0.063 US$/kWh as reported in RENEWABLES NOW. Energy heat utilities are entirely self-sufficient, by burning part of the biomethane or tail gas from FT reactor, eliminating their contribution to the OPEX.

A market research has been conducted to identify average price point for e-SAF and e-methanol. Respectively, it has estimated for eSAF a price point of 1200 US/ton and for e-methanol a price point of 800 US/ton. It is to be noted that the uncertainty of this prices is quite large. Consequently, a sensitivity analysis of product prices and electricity costs (the primary OPEX contributor) will be detailed later in this chapter.

Figure 2.17 reveals that methanol production via the syngas route emerges as the economically preferred process scenario. The process scenario A is potentially economically feasible, but still required and optimization to reduce CAPEX and/or enhance productivity. In contrast, process scenario 3 proves economically infeasible under the assumed e-SAF price.

Process Scenario A: Syncrude (SAF)

Capex			
complexity factor		1	
H2 electr		US$ 25.1M	36 MW
Equipment Total		US$ 430M	
Engineering (10%)		US$ 43 M	
BoP (15%)		US$ 64.5M	
TCI= Contingency (20%) + land and others		**US$ 752M**	
Opex			
	H2	**Compressors**	
size kWh	36,410.4	9000	45,410.4
el price $/kWh	0.063	0.063	
Lifetime	25y		
operative cost	2,851.8$/h		
operativeness	0.95		
operational year	8117h/y		
operative cost	23.1 MUS$/y		
Maintenance (3%)	15.3 MUS$/y		
Depreciation	20.4MUS$/y		
Interest (4%)	20.4MUS$/y		
H2	5,184,840.96kg/y		
O2	41,478,727.68kg/y		
O2 to sell	-154038964kg/y		
Mini Business Case			
Cost per year	106MUS$/y		
SAF Produced	123,139,972.8kg/y		
LCOSAF	**860.16US$/ton**		
SAF Price	1400US$/ton		
IRR	7%		

Process Scenario B: Syncrude (SAF)

Capex			
complexity factor		1	
H2 electr		US$ 150M	218 MW
Equipment Total		US$ 730M	
Engineering (10%)		US$ 73 M	
BoP (15%)		US$ 109 M	
TCI= Contingency (20%) + land and others		**US$ 1.28b**	
Opex			
	H2	**Compressors**	
size kWh	218,100.0	9,000	227,100
el price $/kWh	0.063	0.063	
Lifetime	25y		
operative cost	14,261.9$/h		
operativeness	0.95		
operational year	8117h/y		
operative cost	116MUS$/y		
Maintenance (3%)	28.2MUS$/y		
Depreciation	37.7MUS$/y		
Interest (4%)	37.7MUS$/y		
H2	31,057,440kg/y		
O2	248,459,520kg/y		
O2 to sell	-9903144kg/y		
	256MUS$/y		
	190,744,800kg/y		
	1343.11US$/ton		
	1400US$/ton		
	-10%		

Process Scenario C: Methanol

Capex			
complexity factor		1	
H2 electr		US$ 142M	205 MW
Equipment Total		US$ 399M	
Engineering (10%)		US$ 40 M	
BoP (15%)		US$ 59.9	
TCI= Contingency (20%) + land and others		**US$ 698 M**	
Opex			
	H2	**Compressors**	
size kWh	205,620	45,000	250,620
el price $/kWh	0.063	0.063	
Lifetime	25y		
operative cost	15,738.9$/h		
operativeness	0.95		
operational year	8117h/y		
operative cost	128MUS$/y		
Maintenance (3%)	13.9MUS$/y		
Depreciation	20.7MUS$/y		
Interest (4%)	18.5MUS$/y		
H2	29,280,288kg/y		
O2	234,242,304kg/y		
O2 to sell	38724612kg/y		
Mini Business Case			
Cost per year	207MUS$/y		
Methanol Produced	359,614,824kg/y		
LCOMethanol	**576.26US$/ton**		
e/bio-Methanol Price	800US$/ton		
IRR	11%		

Figure 2-17 Simplified economic estimations for the analyzed processes.

2.7.1 Sensitivity Analyses

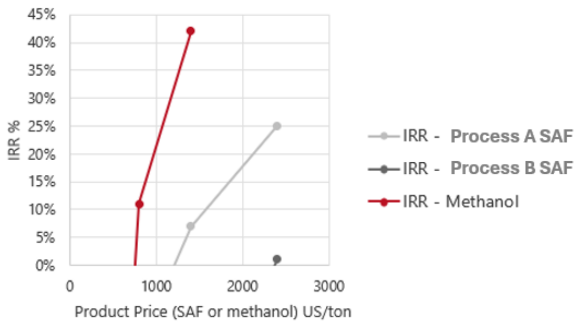
To provide more comprehensive understanding and better evaluate the comparison of business cases, two sensitivity analyses are here presented.

Figure 2.18 illustrates a sensitivity analysis of the business case indicator IRR (Internal Rate of Return) in relation to the final product price. For SAF, three price ranges are selected: the current price for SAF (900 $/ton), a low range future price for SAF (1400 $/ton), and a high-medium future price for SAF (2400 $/ton). This range can be expanded in future analysis. For methanol, three price ranges are also selected: the current price for methanol (365 $/ton), a low range future price for bio-methanol (800 $/ton), and high range future price for e-methanol (1400 $/ton). The latter two prices are derived from the International Renewable Energy Agency.

Process Scenario A: Syncrude (SAF)	
Product Price USD/ton	*IRR – Process A Syncrude*
900	-11%
1400	7%
2400	25%

Process Scenario B: Syncrude (SAF)	
Product Price USD/ton	*IRR – Process B Syncrude*
900	NA*
1400	NA*
2400	1%

Process Scenario C: Methanol	
Product Price USD/ton	*IRR - Methanol*
365	NA
800	11%
1400	42%



*Not possible iterate IRR due to consecutive negative cash flows throughout the period

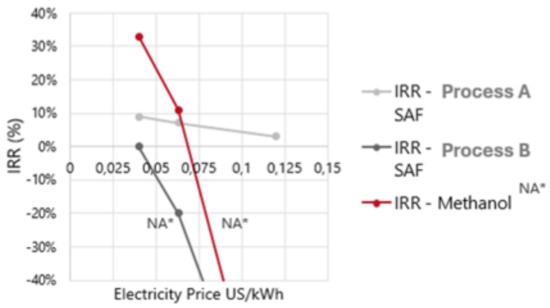
Figure 2-18 Sensitivity analysis of the business case indicator IRR in relation to the final product price.

The methanol process layout exhibits the highest IRR under the lowest product price scenario, indicating its economic feasibility. However, this sensitivity analysis also reveals that the methanol process is the most susceptible to fluctuations in product price, which could be considered a potential drawback. Process B (SAF) demonstrates feasibility only when the SAF price exceeds 1500 $/ton. Moreover, Process B is more sensitive to product price variations compared to Process A (SAF). Figure 2.19 presents an alternative sensitivity analysis focusing on the impact of electricity price, a significant contributor to OPEX.

Process Scenario A: Syncrude (SAF)	
Syncrude Price 1400 US$/ton	
Electricity Price USD/kWh	*IRR – Process A Syncrude*
0.04	9%
0.063	7%
0.12	3%

Process Scenario B: Syncrude (SAF)	
Syncrude Price 1400 US$/ton	
Electricity Price USD/kWh	*IRR – Process B Syncrude*
0.04	0%
0.063	NA*
0.12	NA*

Process Scenario C: Methanol	
Methanol Price 800 US$/ton	
Electricity Price USD/kWh	*IRR - Methanol*
0.04	18%
0.063	11%
0.12	NA*



*Not possible iterate IRR due to consecutive negative cash flows throughout the period

Figure 2-19 Sensitivity analysis of the business case indicator IRR in relation to the electricity price.

Among the analyzed process layouts, Process A (SAF) exhibits the lowest sensitivity to electricity price fluctuations. While the methanol process offers the most favorable economic performance under favorable electricity prices, its susceptibility to electricity price variations raises concerns about its robustness. Process B syncrude (SAF) demonstrates economic feasibility only under the combined conditions of relatively low electricity prices and relatively high SAF product prices.

In summary, the methanol process layout presents an intriguing option from an economic standpoint, but its sensitivity to both electricity and product selling point prices, particularly compared to Process A syncrude/SAF, cannot be overlooked. Process A syncrude/SAF emerges as a relatively robust business case for SAF prices ranging from $1400 to $2400 per ton, and its resilience to electricity price variations stems from its lower reliance on green hydrogen.

As previously mentioned, CO_2 utilization plays a significant role in the process design, costs, and consequently, the overall business case. It is recommended to investigate scenarios involving reduced CO_2 utilization and subsequent conversion into fuels, thereby minimizing the demand of green hydrogen.

Given the results obtained and discussed in the preliminary economic analysis, the methanol process presents lower costs and higher return rates when compared to the syncrude process. Furthermore, the methanol is an established market product, with a defined regulatory framework as well as a consistent market demand. This points to the fact that the methanol process, which is less complex and more flexible in terms of process strategy changes, could be an interesting approach to be further analyzed. Considering that, a refined economic analysis was carried out for the methanol process.

2.7.2 Detailed Methodology – Process C (Methanol)

Understanding the economic feasibility of a project is essential in engineering proposals, and different methodologies can be utilized for this analysis. To analyze the economic feasibility of the methanol production process from synthesis gas, there are three available methods: order of magnitude estimation, the Lang Global Factor method, and the Guthrie Individual Factor method. The latter was chosen since it provides errors in the order of 20 %. Meanwhile, the other two do not guarantee such a reliable result, bringing errors in the range of 35 %.

The Guthrie method was initially developed by Hand, and later improved by Guthrie himself (in 1969). According to this concept, it is possible to estimate the Total Invested Capital (C_{TCI}) of a plant. Each parameter in the cost estimation model will be discussed above.

$$C_{TCI} = 1{,}18 \cdot \left(C_{TBM} + C_{site} + C_{buildings} + C_{facilities}\right) + C_{wc} \qquad (1)$$

The Total Invested Capital (C_{TCI}) can be split into depreciable and non-depreciable capital. The Total Depreciated Capital of an investment is the cost related to equipment that wears out according to its expected lifespan. This means that all assets that have natural loss of value suffer a depreciation of their value. Consequently, after 10 years (on average), their cost will be very small in relation to the purchase value. This variable includes the costs of acquisition and installation of equipment (C_{TBM}), the cost of area preparation (C_{site}), the cost of general installations ($C_{buildings}$), and the cost of utility installations ($C_{facilities}$).

When a certain asset does not suffer physical wear and tear over time, its value at the end of its use remains the same as it was at the beginning of its use. Therefore, it does not suffer depreciation and can be sold for its market value or even more. This capital is called non-depreciable, and it will be considered as the working capital or the start-up costs (C_{WC}). Each cost associated with the Total Invested Capital (C_{TCI}) will be described individually.

2.7.2.1 Total Module Cost (C_{TBM})

C_{TBM} sums up bare-module costs for every process equipment element, from tanks and machinery to computers and software. The bare-module cost of each equipment (C_{BM}) starts with the base price of the equipment (C_{FOB}), then adds in the cost of materials and labor needed to install it (direct field costs), and finally includes additional expenses like shipping, insurance, and overhead (indirect expenses).

$$C_{BM} = C_{FOB} \cdot F_M \quad (2)$$

C_{FOB} is the cost of the equipment calculated with freight and insurance separately, as the transportation of the goods is the responsibility of the buyer. This cost is calculated using the correlations and values established by Guthrie (1974) and Seider et al. (1999), correlations which are different for each piece of equipment. In addition, F_M is the module factor for correcting this FOB cost and varies according to the unit operations (Table 2.16).

Table 2-16 Module factors for different equipments.

Equipments	F_M
Horizontal reactors	4,3
Columns	4,3
Heat Exchangers	3,3
Centrifugal Pumps	3,4
Compressors	3,5

Adapted from: (Seider et al., 2009).

The module prices are calculated and estimated in dollars for a CE index equivalent to 560.4 at the end of 2010. Therefore, it is necessary to correct these values using the following relationship:

$$C_{2023} = C_{2010} \cdot \frac{CE_{2023}}{CE_{2010}} \quad (3)$$

For 2023, the Chemical Engineering Plant Cost Index used was 798.7. This value is available on Chemengonline, of Chemical Engineering (https://toweringskills.com/financial-analysis/cost-indices/). Also, a safety factor of 20% was added in the total bare-module cost.

2.7.2.2 Site Cost (C_{site})

Site preparation and development costs (Csite) can be significant for new plants (grass-roots plants), ranging from 10 to 20% of the total bare-module cost of the equipment (CTBM). However, for an expansion of an existing integrated facility, the cost is typically much lower, falling between 4% and 6% of the CTBM.

2.7.2.3 Buildings Cost ($C_{buildings}$)

The cost of process buildings can be initially estimated at 10% of CTBM. For new plants (grass-roots plants), non-process buildings can be preliminarily estimated at 20% of CTBM. However, for expansions of existing integrated complexes, non-process buildings are typically lower at around 5% of CTBM.

2.7.2.4 Facilities Cost ($C_{facilities0}$)

Offsite facilities encompass utility plants (if the company manages its own utilities), pollution control systems, ponds, waste treatment facilities, offsite tankage, receiving and shipping infrastructure. Additionally, an estimated 5% of CTBM can be allocated for other offsite facilities.

2.7.2.5 Working Capital (C_{WC})

Working capital, beyond fixed and startup costs, bridges the gap between a company's payments and receivables. It covers operational needs like inventory and accounts receivable. Accountants measure it as current assets minus liabilities, including cash, inventory, and receivables on one side, and accounts payable on the other. Typically, a one-month buffer is provided, reflecting standard 30-day payment terms for both purchase and sale of goods. It can be calculated by:

$$C_{WC} = cash\ reserves + inventory + accounts\ receivable - accounts\ payable \quad (4)$$

Each variable can be defined as follows.

Cash reserves: to cover expenses such as raw materials, utilities, operations, maintenance, overhead, property taxes, insurance, and depreciation, a 30-day buffer of cash reserves is required. This equates to 8.33% of the annual cost of manufacture (COM), assuming a 30-day period represents one-twelfth of a year. The annual cost of manufacturing (COM), which is consider as the OPEX value, is the sum of the direct manufacturing costs (that includes feedstocks, utilities, labor-related operations, and maintenance), the operating overhead and the fixed costs (property taxes, insurance, and depreciation).

Inventory Working Capital: A seven-day supply of liquid and solid products is held at the sales price, assuming weekly shipments. This represents 1.92% of annual sales for liquid and solid products only.

Accounts Receivable: Thirty days' worth of product receivables are held at the sales price, amounting to 8.33% of annual sales for all products.

Accounts Payable: The company maintains a thirty-day buffer for feedstock payables at the purchase price, representing 8.33% of annual feedstock costs.

2.7.2.6 CAPEX and OPEX estimations

The results calculated for the CAPEX of the methanol plant are available in Table 2.17. It is important to mention that the CAPEX from renewable plants is described in Chapter 3. The results calculated for the OPEX of the methanol plant are available in Table 2.18.

Table 2-17 Total CAPEX investment costs.

Description	Value (US$)
Total Module Cost (CTBM)	$350.762.624,87
Working Capital Cost (CWC, equation 35)	$52.521.011,63
Site Cost (Csite)	$52.614.393,73
Buildings Cost (Cbuildings)	$70.152.524,97
Facilities Cost (Cfacilities)	$ 114.478.376,73
Total Capital Invested Cost (CTCI, equation 32)	$746.370.357,58
CAPEX from renewable plants	$ 652.000.000,00
Total CAPEX Investment Costs	$1.398.370.357,58

Table 2-18 Total OPEX investment costs.

Description	Value (US$)
Raw Material Costs	$ 58.815.407,58
Utilities Costs	$ 100.981.048,20
Labor-Operations Costs	$ 341.141,30
Maintenance	$62.446.441,14
Depreciation	$44.701.188,91
Taxes and Insurance	$6.938.493,46
Total OPEX Costs	$233.275.085,94

While the analyzed biogas-to-methanol conversion case shows a similar CTCI to previously presented ones, renewable plants like those in the next chapter have significantly higher CAPEX estimates. This increase mainly results from additional equipment, working capital, scale, and associated utilities. Notably, site, building, and facilities costs are based on the total module cost, further escalating with higher equipment costs. To isolate the operational aspects of the process, the OPEX and sensitivity analysis in this work did not incorporate the capital expenditure (CAPEX) associated with the renewable energy plants.

A detailed analysis of OPEX contributors was performed, aiming to identify the optimal utilities for key equipment like heat exchangers and reactors. While further refinement is required, the focus was on readily available, non-toxic, and cost-effective options like water and steam. However, due to the high-water demand of some heaters, heating oil was investigated as an alternative utility. To account for potential inefficiencies and operational cycles, a 5% loss factor was incorporated into the annual production cost/OPEX estimation. The analysis revealed that electricity was the primary contributor to OPEX due to the significant energy requirements of gas compression and electrolyte operation. This emphasizes the importance of optimizing these processes for improved energy efficiency, ultimately leading to reduced overall operating costs.

Regarding the specific OPEX parameters, it is important to mention that the labor-operation cost was estimated based on a general plant. Also, the maintenance was considered as 9% of all the depreciable capital calculated previously (C_{TCI}), the taxes and insurance were 1% of this same capital and the depreciation was 8% of the difference between the C_{TCI} and 118% of the facilities costs ($C_{facilities}$).

2.7.2.1 Sensitivity Analysis

To provide more comprehensive understanding and better evaluate of the methanol process, a sensitivity analyses is here presented.

Some considerations were made to perform this analysis: the methanol selling price is defined as 1500 US$/ton, and the MeOH production is 31,5 tons per hour. So, the gross annual revenue is $374.397.130,80.

Taking into account negative factors like annual depreciation and production costs, it was able to estimate the project's Internal Rate of Return (IRR). This hypothetical discount rate, based on projected cash flow, helps determine if the investment is financially viable. Refer to Table 2.19 for the specific cash flow projections.

Table 2-19 Calculated IRR for methanol production.

Case Description	IRR
Methanol Cost: 1000 US$/ton	-3,87 %
Methanol Cost: 1200 US$/ton	2,91 %
Methanol Cost: 1500 US$/ton	12,92 %

To understand how changing production or price impacts profitability in methanol production, the break-even point was estimated. This point, where revenue and expenses equalize, reveals no profit or loss. The analysis considered scenarios where either production volume or selling price fluctuated. For economic viability, either a minimum production of 23,4 tons/h of methanol or a minimum selling price of 1113,7 US$/ton is necessary. This ensures zero profit or loss, making the process feasible.

Though the provided cost figures provide a glimpse of potential expenses, it is important to note that production and sales at the selected site for the methanol plant may vary considerably. Costs associated with electricity, raw materials, labor, equipment, and utilities are particularly vulnerable to change. This uncertainty, coupled with the 20% potential error in the cost estimations by Guthrie's methodology, underscores the need for flexibility and adaptability in planning.

2.8 Conclusions and Highlights

After a careful evaluation of the possible process configurations to use biogas as a raw material to obtain either syncrude or methanol, some process scenarios were obtained. Three scenarios focused on syncrude production. The first scenario served as a baseline, involving all essential unit operations for converting biogas to syncrude without any process recycle. The second scenario (A) incorporated tail gas recycling into the reforming stage, along with a pre-reformer, to enhance process yield. The third syncrude production scenario (B) aimed to address CO2 utilization, as the process does not fully convert all CO2 present in the biogas, necessitating the separation of a significant amount of CO2 from syngas before Fischer-Tropsch synthesis. As a simpler alternative for biogas utilization, methanol production from syngas (scenario C) was also evaluated as a fourth process scenario for comparison purposes.

The technical feasibility of each process scenario layout was evaluated, and a simplified economic assessment was conducted. Each process configuration has its own unique advantages and disadvantages in terms of cost, yield, hydrogen, and water utilization, for instance, making them suitable for specific local conditions and requirements. However, based on economic comparisons, certain scenarios may emerge as promising candidates for process implementation.

Technically speaking both processes are feasible, despite optimization of process design and heat integration being necessary in future analysis for all of the process configurations evaluated in this work. The syncrude route present higher process complexity and lower flexibility, and its phased implementation should be regarded as a strategic approach. For this route, it is technically advisable to include the hydrocracking step in the simulations and also to select a narrower carbon chain interval, so the economics could be better evaluated, and the product transportability could be facilitated. The methanol route, by its turn, has lower degree of complexity and higher degree of flexibility, which could be beneficial in case of future changes in strategy of the process.

In the economic side, both syncrude (scenario A) and methanol (scenario C) could reach a levelized cost within the range of estimated future prices for synthetic fuels. Scenario B of syncrude production is most likely to be discarded or to have its process design revised. Methanol levelized cost is more sensitive to electricity price due to the relatively large green H2 electrolysis unit. Finally, renewable energy plant size due to large green H2 requirement has a large impact on CAPEX and OPEX.

At this juncture, considering all the discussions, one could either proceed with further evaluation and comparison of two or more process scenarios or based on current indicators, select a single process scenario for thorough evaluation.

Finally, it is also important to mention that, in general, the production of methanol is comparatively less complex than that of syncrude, resulting in diminished associated economic risks. While the methanol process may be economically viable, its feasibility is susceptible to fluctuations in technical factors, market conditions, and regulatory requirements, thereby increasing associated risks.

2.8.1 Optimization Analysis

The simulations conducted in this study aimed to demonstrate technical feasibility and provide input data for economic analysis. Consequently, due to time constraints, optimizations related to process efficiency and heat integration were not carried out. The primary recommendations regarding process optimization requirements will be outlined in this section.

- Water scrubber: the water scrubber operating performance need to be optimized in order to reduce the water consumption. Although, as previously mentioned, the water consumption of the water scrubber is compliant with literature reported ranges, a reduction of water need would be highly beneficial for the process economics and water demand. The effect of some variables could be accessed, such as the pressure, the temperature, and the input of some recycle. Additionally, it is crucial to examine various processes for conducting biogas upgrading and separating CH_4/CO_2. Given the elevated CO_2 content in the mixture, alternative technologies should be explored, including chemical absorption using amines, pressure swing adsorptions, or even a membrane separation system. The optimal approach is to thoroughly study and compare these methods to gain a comprehensive understanding of the actual requirements of the process.
- Utility types and conditions: simple utilities were chosen due to time constrains. Overall, water usage was considered. Thermal fluids such as heating oil were only chosen in the equipments where the water consumption would be really high, resulting in high equipment size besides the water demand. Thus, utility optimization must be performed, by considering different types of utilities and the equipment needed to generate them in the economic analysis. It is also important to analyze the best conditions (temperature, pressure, phase) for each chosen utility to minimize the overall costs.
- Heat integration: Heat integration serves as an effective means to alleviate energy demands in a process plant. However, in this analysis, only the most basic form of heat integration was implemented. Thus, it is essential to explore additional potential heat integration opportunities and assess whether modifications to the initially proposed scheme are warranted. Moreover, it is crucial to investigate the feasibility of generating utilities, such

as steam, from the surplus heat generated by the plant. If feasible, this could significantly diminish the demand for the required utilities.

- Water utilization: The evaluated process generates significant quantities of water as a by-product. Consequently, it is imperative to conduct thorough and optimized water treatment and reuse processes to minimize the overall water consumption. This would not only contribute to reducing the costs associated with this demand but also serve to mitigate some of the environmental impacts that the company could incur.

2.8.1.1 Methanol Plant Purge

The usual syngas to methanol conversion reported in the literature is quite low (about 25%), which causes great amounts of unreacted species to be present in the product stream. Recycle strategies need to be implemented for the process to be economically viable, but since the conversion is low, high recycle rates will ultimately imply in non-reacting species accumulation in the system and convergence issues in simulations. A research work in the literature report recycle rate of 95% for one configuration of the studied process (Sarvestani & Maria, 2022), for example. Clearly, for commercial applications, careful optimization must be performed so this rate is increased, and the purge rate is decreased. There are technical suggestions for addressing the purge stream in methanol plants in the literature (some of which for natural gas-based methanol process) (Advanced Extraction Technologies, n.d.; Mirvakili et al., 2016; Sarvestani & Maria, 2022) since this purge stream has a high hydrogen and carbon monoxide content. In the present project, it is especially important to address this stream since high-cost green hydrogen is being introduced in the process, and environmental footprint is an especial concern.

The suggestions in the literature to address traditional methanol process purge stream include burning (due to its high energetic content), converting to other products as well as including gas separation units to separate the components of interest and recycle them into the process. This last alternative, for example, is currently commercially offered (Air Liquide, n.d.). In the present project, low added value options such as burning would be the last preferred option (otherwise economically advisable).

For the methanol simulation, 91% of light gases recycling is considered as mentioned in the report, impacting in high amounts of valuable molecules leaving the process without conversion. Due to time constrains, strategies to enhance this recycle rate were not implemented, but they are required in future project refining to enhance the process economics and to assess the impact of higher recycle rates in process costs. Potential strategies to address this purge stream could be the implementation gas separation units or more than one methanol reactor. It should be noted that these strategies will ultimately and, probably importantly, impact the CAPEX and the OPEX, and detailed evaluation should be performed to evaluate if they are economically attractive. As suggested in the report, the most attractive process scenario should be evaluated in detail and further optimized.

The same way as for the other scenarios, the electrolyzer presence and need should be carefully evaluated, since depending on the reforming and RWGS conversions, only small amounts of green hydrogen input may be needed for the process, and the need for fresh green hydrogen input may be overcome by changing the process configuration, operation conditions and/or including additional unit operations.

2.8.2 References

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2.9 Technologies Review

This chapter will provide a process description of the main simulated unit operations. The process unit operations were divided into the main transformation steps that comprise the considered system.

2.9.1 Water Scrubbing

In general, biogas is a mixture of CH4, CO2 and other unwanted compounds. To achieve the proposal of this work, these major components need to be separated into two process streams. There are different technologies to perform this separation, called biogas upgrading (Angelidaki et al., 2018).

Water scrubbing is a process that can be classified as physical absorption. It is based on the difference in solubility that a mixture of gases contains when it is dissolved in a solution responsible for this scrubbing, which in this case is water itself. It is the most widely used process in the industry for upgrading biogas, with 41 % of the world market present. For this reason, it was selected as the upgrading method on this work to perform the separation between CH4 and CO2 (Niesner et al., 2013). A key concern in water scrubbing is the high water consumption for CH4/CO2 separation (200 m^3/h per 1,000 Nm^3/h biogas, as per Angelidaki et al., 2018). Optimization is crucial to minimize water usage and improve process efficiency.

The water scrubbing system consists of two stages. The initial one involves an absorption column, responsible for removing the CO2 content from the biogas, by using pressurized water as a solvent. This operation is followed by a stripping column, which is responsible for regenerating this solvent. The operational condition of the first column (absorber) is given at temperatures from 30 to 50°C and pressures from 9 to 12 bar (Ashraf et al., 2015; Bauer et al., 2013). As for the second equipment (stripping column), the water can be regenerated by decompression to atmospheric pressure, resulting in the release of CO2 (Angelidaki et al., 2018).

In the provided block flow diagram, there are three feed streams, which the conditions are presented on it. The biogas was first prepared by adjusting its pressure and temperature before being introduced at the bottom of the absorber column. To perform this adjustment, it was used a system of two isentropic compressors with 85 % efficiency.

The first one has a discharge pressure of 4 bar. A heat exchanger was implemented to reduce the temperature of the mixture to 40 °C, with a pressure drop of 0.3 bar. Then, a second compression stage is responsible for increase the pressure to 12.3 bar, followed by another heater to adjust the temperature to 40 °C. Meanwhile, a water stream was also pressurized to be fed on the top of the absorber column, in a countercurrent flow. A pump with 85 % efficiency was used, with a discharge pressure of 12 bar. On both equipment, the simulation was performed using the Peng Robinson thermodynamic model and only the vapor phase was considered as valid phase.

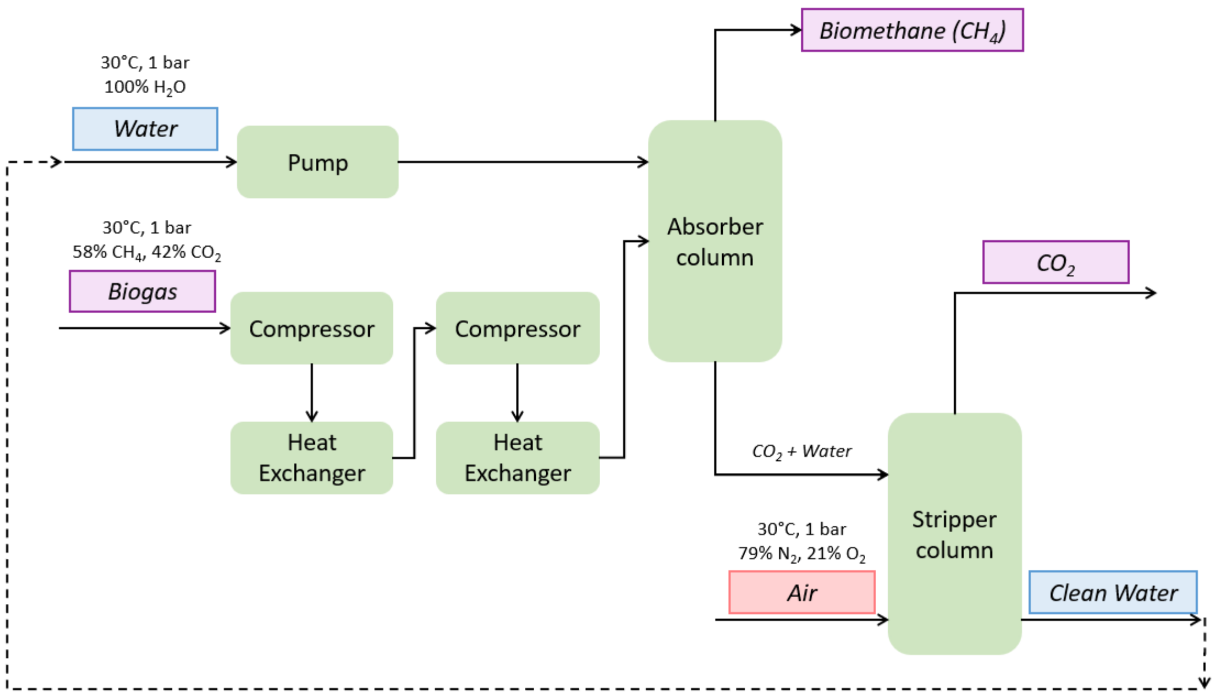

Figure 2-20 Block flow diagram for the water scrubbing system for CO2/CH4 separation.

To model the absorption and the stripper columns, some general considerations were made: the thermodynamic model used was the electrolytic NRTL (electrolyte non-random two liquids); the compounds CO2, H2S, NH3, N2, O2 and CH4 were considered Henry's components; columns operate in equilibrium without condenser and reboiler; valid phases present in the system are liquid and vapor; there are chemical reactions taking place in the absorber column, which are arranged in the fed biogas was considered just a mixture of CH4 and CO2. Also, both columns have 20 equilibrium stages, the liquid stream was fed into the first stage (1st) and the vapor stream on the last one (20th). The absorber operates at a pressure of 12 bar, while the stripper operates at 1 bar, and no pressure drop was taken into account.

Table 2-20 CH4/CO2 separation system reactions.

Type	Reaction
Equilibrium reaction	$NH_3 + H_2O \leftrightarrow NH_4{}^+ + OH^-$
Equilibrium reaction	$HS^- \leftrightarrow H^+ + S^{2-}$
Equilibrium reaction	$H_2S \leftrightarrow H^+ + HS^-$
Equilibrium reaction	$H_2O \leftrightarrow H^+ + OH^-$
Equilibrium reaction	$CO_2 + H_2O \leftrightarrow H^+ + HCO_3{}^-$
Equilibrium reaction	$HCO_3{}^- \leftrightarrow H^+ + CO_3{}^{2-}$
Salt	$NH_4HS_{(s)} \leftrightarrow NH_4{}^+ + HS^-$

Two streams were produced in the initial column. The upper stream predominantly comprises biomethane, whereas the lower stream consists of a mixture of water, CO2, and other impurities. The latter is introduced into the stripper, where the solvent is regenerated and recirculated to the absorber. The CO2 is separated and exits as part of the upper stream from this column.

2.9.2 Steam Methane Reforming

Steam Methane Reforming (SMR) is a technological route to produce synthesis gas using biomethane as the main reactant. It has industrial and large-scale applications and usually, this route can be also applied in the production of H2 (Ramos et al., 2011).

The main reaction in SMR is an endothermic process and occurs between methane (CH4) and water vapor. The operational temperature is typically around 800 °C, while pressures range between 15 and 30 bar. The resulting syngas attains H2/CO molar ratio of approximately 3 and the catalyst commonly employed in this reforming process is nickel-based (Chouhan et al., 2021; Froment & Xu, 1989).

This entire system can be summarized in one main unit: a reforming reactor. Prior to this reactor, adjustments must be made to the feed stream (biomethane) to align with the specified conditions for this unit. The CH4 stream is pressurized to 24 bars using an isentropic compressor with 85 % efficiency. After that, it is pre heated to 600 °C in a heat exchanger, aiming to reduce the heat duty of the reactor.

Meanwhile, it is important to mention that the water content necessary to the SMR is first fed into a pre-reformer stage for the FT synthesis. This specific process will be discussed in topic 2.7. The resulting stream of this unit, which consists in a mixture of different compounds, primarily including CH4, CO2, H2O, and syngas, can be combined with the pure biomethane stream and subsequently introduced into the reforming reactor. The temperature and pressure conditions of both streams closely match, so it is not necessary to add a buffer tank for equalization.

Having both of these streams at the appropriate conditions, they can be introduced into the SMR reactor. This unit operates as a kinetic reactor, described in Chapter 7. The conditions were defined as 900 °C and 24 bar. Furthermore, the current reactions at chemical equilibrium are outlined. All of them were treated as reversible reactions and since steam is one of the primary reactants of SMR, solid carbon formation was neglected (Chouhan et al., 2021). For all these equipment on this stage, the thermodynamic model considered on the simulations was Peng Robinson.

Table 2-21 Reactions of the steam reforming system.

Nº	Name	Reaction
r1	Steam Reforming main reaction	$CH_4 + H_2O \leftrightarrow CO + 3\,H_2$
r2	Reverse Water-Gas shift	$CO_2 + H_2 \leftrightarrow CO + H_2O$
r3	Reverse Sabatier reaction	$CH_4 + 2\,H_2O \leftrightarrow CO_2 + 4\,H_2$

There are a few points of attention in the SMR process simulation. Since the operational temperature achieves values near to 1000 °C, an external heat source is required for heating the reactor. Because of that, the purified biomethane stream in the water scrubbing process was separated, so that 28 % of it was allocated for power generation to the SMR reactor. Despite this, and the requirement for a feedstock enriched in CH4 with lower CO2 contents, most studies related to SMR report minimal coke formation as a significant advantage (Froment & Xu, 1989; Gangadharan et al., 2012).

2.9.3 Adiabatic Post-Converter

The Reverse Water Gas Shift (RWGS) is a side reaction that takes place within steam methane reforming but can also be conducted independently. It is an endothermic chemical reaction, in which the CO2 is reduced to CO, while consuming H2. As such, it has the potential to lower the syngas H2/CO molar ratio, particularly when employed after the SMR process. For the process to occur satisfactorily the formation of CO, temperatures above 700 °C and H2/CO2 mixture ratios equal to 3 are frequently employed (González-Castaño et al., 2021).

A RWGS unit, combined with a previous SMR unit, comprises an operation known as ReShift. In this scenario, the syngas produced in the reforming reactor is directed to a subsequent reactor, where the RWGS will occur, increasing the CO content in the mixture and adjusting the H2/CO ratio for Fischer-Tropsch synthesis or the Methanol synthesis. The second reactor is called adiabatic post-converter (APOC), and its modeling is based on the Topsoe ReShiftTM technology (Baltrusaitis & Luyben, 2015; Mortensen et al., 2020).

Taking all these factors into account, the initial stage in this APOC block involves introducing the CO2 stream into the process, which originates from the stripper column in the water scrubbing unit. This stream needs to be pressurized and heated to attain similar conditions to those of the syngas generated in the SMR. This procedure is carried out using a sequence of compressors and heat exchangers. The compressors are isentropic and have an efficiency of 85 %, with a maximum outlet temperature of 170 °C. Additionally, all the heaters have a pressure drop of 0.3 bar.

As presented in the SMR, the APOC operation is also consolidated in a single reactor. After adjusting the operational conditions, both streams (syngas and CO2) can be combined and introduced into the RWGS reactor, in which the reactions mentioned on are occurring.

Name	Reaction
Bi-reforming	$3\,CH_4 + 2\,H_2O + CO_2 \leftrightarrow 8\,H_2 + 4\,CO$
CO2 Methanation	$CO_2 + 4\,H_2 \leftrightarrow CH_4 + 2H_2O$
CO Methanation	$CO + 3H_2 \leftrightarrow CH_4 + H_2O$
Reverse Water-Gas shift	$CO_2 + H_2 \leftrightarrow CO + H_2O$

As defined for the SMR, this unit also operates as an equilibrium reactor, following the principle of minimizing Gibbs free energy. Phase and chemical equilibrium were computed under a pressure of 25.5 bar and a heat duty of 0.1 MW, which characterizes a condition close to adiabatic operation of the equipment. All the unit operations in this stage were simulated using the Peng Robinson thermodynamic model.

The exit stream of this reactor contains CO, H2, H2O, CH4 and CO2 and needs to be adjusted to enter the Fischer-Tropsch synthesis or the Methanol synthesis. This aligns with the objective of maximizing syngas purification by reducing its water and CO2 content.

2.9.4 Syngas Upgrading

Certain compositional limitations should be respected for the syngas before its introduction into the FT synthesis to prevent issues such as product accumulation, catalyst deactivation, and other problems within the reactor (Maitlis & de Klerk, 2013).

CO2 acts as an inert compound in the FT synthesis, and its concentration in the syngas must be carefully controlled. The presence of CO2 in the syngas can lead to accumulation within the system, necessitating larger purges and restricting the recycling stream. Since CO2 is introduced into the Re-Shift reactor, which does not achieve 100 % of conversion, it is important to remove this compound from the syngas before it enters the FT reactor. Furthermore, water, a byproduct of the Re-Shift reactor, must be removed before the FT synthesis. Considering these aspects, a syngas conditioning/upgrading step was proposed.

To remove the water content from syngas, a system comprising a sequence of three heat exchangers and a flash tank was proposed. This setup is designed to lower the mixture temperature to 40 °C, condensing the H2O. Subsequently, in the flash tank, the condensed water is collected as a separate stream. The pressure on this tank was established at 24.6 bar and it was modeled using the NRTL thermodynamic model. In the case of the heaters, a pressure drop of 0.3 bar was accounted for in each of them and the Peng Robinson equation of state was employed to predict the system's behavior.

Regarding CO2 removal, there are several options available in the market to perform this separation. CO2 absorption by MEA solution (monoethanolamine) is a widely applied industrial solution and it was chosen due to its technological maturity (Angelidaki et al., 2018; Taipabu et al., 2023).

The process of CO2 chemical absorption by a MEA (Monoethanolamine) solution involves a two-column system. The initial column serves as an absorber, where the MEA solution reacts with the CO2 present in the syngas. Subsequently, in the second column, known as the stripper, CO2 is released by heating the mixture, allowing the MEA regeneration, which is then recycled back into the first column. A few reactions between the electrolytes present in the system take place, as mentioned below in Table 2.5.

Table 2-22 MEA system reactions.

Nº	Reaction
r1	$H_2O + MEAH \leftrightarrow MEA + H_3O^+$
r2	$2H_2O \leftrightarrow OH^- + H_3O^+$
r3	$HCO_3^- + H_2O \leftrightarrow CO_3^{2-} + H_3O^+$
r4	$CO_2 + OH^- \rightarrow HCO_3^-$
r5	$HCO_3^- \rightarrow CO_2 + OH^-$
r6	$MEA + CO_2 + H_2O \rightarrow MEACOO^- + H_3O^+$
r7	$MEACOO^- + H_3O^+ \rightarrow MEA + CO_2 + H_2O$
r8	$CO_2 + 2\,H_2O \leftrightarrow H_3O^+ + HCO_3^-$
r9	$MEAH^+ + H_2O \leftrightarrow MEA + H_3O^+$
r10	$MEACOO^- + H_2O \leftrightarrow MEA + HCO_3^-$

The reactions 1-3 are governed by the equilibrium condition while the reactions 4-7 by kinetics. The kinetics data considered for those reactions are presented on. Also, the electrolyte solution chemistry considered the equilibrium reactions 2-3 and the reactions 8-10.

Table 2-23 Kinetic parameters for reactions 4-7.

Nº	K	Ea (cal/mol)
r4	$4.32.10^{13}$	13,249
r5	$4.38.10^{17}$	29,451
r6	$9.77.10^{10}$	9,855.8
r7	$3.23.10^{19}$	15,655

Regarding the reactions governed by the kinetics, power law expressions were considered with kinetic constants taken from the literature (values next to the reactions from/derived from: reaction 4 (Pinsent et al., 1956); reaction 5 values from (Pinsent et al., 1956) and equilibrium constants of the reactions 4 and 5; reactions 6 and 7 (Hikita et al., 1977)).

The absorption simulations were performed using the electrolyte NRTL thermodynamic model in the equilibrium mode, considering an absorption column followed by a centrifugal pump and a heat exchanger, to adjust the conditions for the second column (stripper), used to regenerate the solvent.

Both columns were simulated with 20 equilibrium stages. The absorber operated at a temperature of 40°C and 7 bar, and the operational conditions of the stripper were 120 °C and 2 bar. The mass composition of MEA in the solvent solution was 20% and 80% water. A make-up of water in MEA is needed to compensate for the losses in the product stream (Angelidaki et al., 2018; Awe et al., 2017; Taipabu et al., 2023).

In the simulations for syngas cleaning, a water scrubbing system was also evaluated. However, when contrasted with the MEA simulations, it became evident that this method would require a significantly larger quantity of solvent, in this instance, water. This would result in disproportionately large and costly columns. Consequently, only the MEA solution was chosen for the CO2 separation from the syngas due to its more favorable economic and practical considerations.

2.9.5 Methanol synthesis

Methanol (CH3OH or MeOH) is an important industrial chemical, used on a large scale in the plastics industry, in the extraction of various products and as a solvent. It is also useful in the organic synthesis of various chemical intermediates, such as formaldehyde, methyl chloride, acetic acid, methylamines, methyl methacrylates and used in the transesterification process of triglycerides to produce biodiesel (IGP Energy, 2016). On a global scale, a significant portion of the industrial production of methanol comes from synthesis gas (CO + H2), either through the gasification of coal or biomass, or through the reforming of natural gas (Zhong et al., 2020).

The standard parameters for methanol synthesis encompass a temperature range of around 230 to 270 °C and a pressure ranging from 50 to 100 bar to favor the conversion of reactants (BISOTTI et al, 2021). The hydrogenation reactions occurring in the reactor are exothermic, so optimal temperatures are required to balance kinetic and equilibrium. The prevalent catalyst employed for this synthesis is copper-zinc-aluminum based (Cu-Zn-Al). The typical conversion rate of CO to MeOH is 25% (Yang & Ge, 2016). To enhance process efficiency, numerous methanol production facilities recycle unconverted gases, such as CO and CO2, back into the reactor.

The syngas conversion into methanol can be conducted by a main unit operation, which is a kinetic reactor. Preceding this step, an essential system for extracting a significant amount of water from the syngas coming from the Re-Shift operation is required, comprising coolers and a flash tank. Subsequently, a pressure adjustment system for the methanol reactor is implemented, incorporating two compression units and heaters to elevate the pressure to 70 bar and the temperature to 270 °C. The compressors are isentropic and have an efficiency of 85 %, with a maximum outlet temperature of 170 °C. Additionally, all the heaters have a pressure drop of 0.3 bar.

Once the syngas is attuned to the specified conditions, it is introduced into the methanol reactor. This unit functions as a kinetic reactor, as elucidated in Chapter 7. The operating conditions are set at 270 °C and 70 bar. Additionally, the current reactions occurring at chemical equilibrium are detailed in Table 2.24, with all reactions treated as reversible. In this phase, the thermodynamic model applied in the simulations is based on the Peng Robinson formulation.

Table 2-24 Syngas-To-Methanol Reactions.

Nº	Name	Reaction
r1	CO_2 hydrogenation	$CO_2 + 3\,H_2 \leftrightarrow CH_3OH + H_2O$
r2	Reverse Water Gas Shift (RWGS)	$CO_2 + H_2 \leftrightarrow CO + H_2O$
r3	CO hydrogenation	$CO + 2\,H_2 \leftrightarrow CH_3OH$

2.9.5.1 Product Separation Section - Methanol

The MeOH reactor produces a mixture of water, methanol, CO2, CH4, and unreacted syngas. To separate the water, the mixture first undergoes cooling in a heat exchanger to condense the water and methanol. The temperature is reduced to 30°C. Then, the cooled mixture enters a distillation column with 15 equilibrium stages. This column utilizes a partial condenser and a kettle reboiler to achieve the desired separation at a pressure of 28.7 bar. The reflux ratio is set to 1 for optimal operation.

The distillation column effectively recovered 98.5% of the water in the bottom stream. However, due to the partial condenser, two product streams were generated. The vapor stream, containing unreacted syngas, CO2, CH4, and trace amounts of methanol, is recycled back into the system to enhance methanol synthesis conversion. This stream is first compressed to 70 bar to achieve a 91% recycle rate. Meanwhile, the liquid stream containing water, methanol, and dissolved CO2 undergoes further processing. A valve expands the mixture, aiding in CO2 removal. Finally, a flash tank efficiently separates the remaining water and CO2 from the purified methanol, achieving a 98.5% pure main product.

2.9.6 Fischer-Tropsch synthesis

As previously mentioned, the Fischer-Tropsch synthesis consists of surface polymerization reactions using syngas (a mixture mainly of CO and H2) to obtain a variety of hydrocarbon chain length products. As the main purpose of the considered process is to produce hydrocarbons in the range of the sustainable aviation fuel (SAF), the low temperature Fischer-Tropsch (FT) was chosen. The previous analysis regarding FT temperature and pressure presented in the first report of this work indicated the need of a balance between the temperature and the reaction pressure aiming to obtain reasonable conversions and a balance between methane and higher hydrocarbons formation. Considering this, the temperature of 220 ˚C and the pressure of 25 bar were chosen for the FT reactor operating conditions. At the first moment a CSTR reactor was simulated aiming to be approximate with a slurry bubble column reactor. Besides CO, H2 and some other molecules present in the system, n-paraffins and 1-olefins with chain length between 1 and 30 carbons were considered in the system. Each hydrocarbon chain formation reaction was considered separately with its formation rate. For this purpose, a kinetic model based on the utilization of a Re promoted Co catalyst considering the CO insertion mechanism was chosen. Minority products such as oxygenates, and 2-olefins were disregarded. The kinetic model allows for the prediction of temperature, pressure and reactants composition variations in the product formation rates. The kinetic modeling equations are presented in Appendix A.

2.9.6.1 Product Separation Section – Syncrude

At the outlet of the FT reactor, a stream with hydrocarbon products, unreacted syngas, water, among other components present in the system is obtained. Given the significant amount of unreacted syngas, recycling it back into the process could enhance the process economic feasibility and efficiency. To achieve this, the unreacted syngas and eventually other compounds must be separated from the main product – it is important to mention that this step differs significantly from the syncrude upgrading/fractionation, from which purpose is to segregate it into usable products, like biofuels.

To separate the fractions of unreacted syngas and lighter hydrocarbons from the fractions of higher molecular weight hydrocarbons, a scheme similar that reported by (de Klerk, 2008) for the LTFT synthesis was proposed.

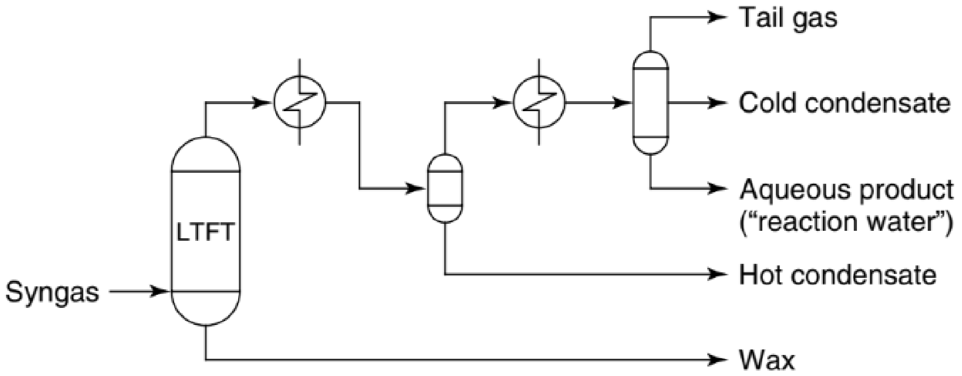

Figure 2-21 Generic FTS product recovery scheme (de Klerk, 2008).

The separation equipment is employed to initially remove the heavier hydrocarbon fractions, including waxes. By gradually cooling the mixture, it serves to partially and preliminarily separate the syncrude, aiming to obtain the desired fraction of this process step. The separation was performed using flash tanks. Since the final process will probably use a fixed bed reactor for the FT synthesis, the separation of a liquid product stream directly in the reactor, as shown in the Figure 2.4 is not possible, and a flash tank is used for this purpose. Furthermore, in the process simulation, the use of a triphasic flash for water separation proved to be a more effective option than employing two flash tanks at different temperatures.

After an evaluation, three flash tanks were implemented. The effect of a pressure drop preceding the flash tanks was examined, and it was found to be either non-beneficial or detrimental to the separation of components. Since reducing the pressure would imply that the recycle stream need to be recompressed to enter the system, the product separation step was operated at the reaction pressure (around 25 bar), considering only equipment pressure drop. Through this configuration, it was possible to separate the syncrude (herein considered as hydrocarbon chains of C5+), water and a fraction containing the unreacted syngas and lighter hydrocarbon fractions.

The first flash tank (180 °C and 25 bar) performed the separation of the heavier hydrocarbons (waxes), with cut fraction at approximately C20+. The second flash tank (30 °C, 23 bar) was able to remove 98 % of the water present in the FT product stream, and two hydrocarbon streams: one of heavier ones, with cut fraction in C7+, that joined the syncrude product; and another with lighter hydrocarbons. Finally, the third flash tank (30 °C, 24 bar) separated at the bottom a stream with approximately C4+ hydrocarbons, and at the top a stream containing the unreacted syngas and the remaining hydrocarbons, mainly comprising 1 and 2 carbons, but also with some amount of C3-C5 hydrocarbons, for example. These heavier hydrocarbons will be reformed in the pre-reformer aiming to increase the amount of syngas in the process, before returning the process in the SMR reactor.

Ideally, if all the hydrocarbons are separated from the unreacted syngas, a pre-reformer would not be needed and the smaller flow of the recycle stream would imply in smaller equipment size. However, the separation of the lighter hydrocarbons (specially C1 and C2) of syngas would demand highly complex and costly unit operations, such as cryogenic separation. Thus, a pre-reformer was inserted in the process to form syngas by the reforming of these heavy hydrocarbons of the recycle stream. The methane formed during the FT synthesis was reformed in the SMR, after the pre-reforming step.

Replacing the third flash by a distillation column was evaluated during the process simulations, aiming to verify the effects of a better separation between the C1, C2 and C3+ fractions. However, it was concluded that this distillation column was not justified since the C3+ hydrocarbons flow in the recycle stream was very low, representing a non-viable recovery.

2.9.7 Pre-reformer

According to Topsoe technology, the Re-Shift process includes an additional unit known as pre-reformer. In this unit, which precedes the steam reforming step, the required steam for the SMR is introduced along with heavy hydrocarbons (HC) recycled from an exhaust gas stream of the Fischer-Tropsch reactor. Its purpose is to reform these compounds to prepare the mixture for the subsequent SMR stage.

As previously mentioned, the inclusion of this step modifies the steam supply to the SMR. Instead of entering directly to the reforming unit, steam is added on this pre-reformer reactor. The water is compressed to 26 bars in a centrifugal pump and preheated in another heat exchanger until it reaches its saturated steam condition. Subsequently, the stream is blended with the recycled stream containing heavy hydrocarbons (HC), and the mixture is passed through a heat exchanger to raise the temperature to 600°C.

The conditions of the pre-reformer are like the APOC reactor: 25.5 bar and an adiabatic operation, with 0.01 MW. This unit also operates as an equilibrium reactor, following the principle of minimizing Gibbs free energy, with the Peng-Robinson thermodynamic model applied on the simulation. Again, the exit stream, at 720 °C, is subsequently combined with the biomethane stream at the beginning of the process and enters the SMR unit.

2.9.8 RWGS

The syngas generated in the Re-Shift process, that includes the SMR and APOC units, must be adapted to meet the requirements of the Fischer-Tropsch (FT) process, particularly concerning CO2 and water content. Typically, CO2 removal is achieved through chemical absorption, using amine-base solvents, such as MEA or DEA (as mentioned in section. This resulting stream, primarily composed of CO2, can serve different purposes, one of which is its conversion back into syngas by the previously mentioned RWGS reaction.

The new stage consists of a single equilibrium reactor unit, where only the RWGS reaction is considered, as mentioned in Table 2.4. It operates at 1000 °C and 25 bar, with only the vapor phase being relevant within the equipment. The thermodynamic model used to predict the behavior of this system is also the Peng-Robinson equation of state. Moreover, it may be necessary to introduce a hydrogen stream, to promote the direct reaction. The H2/CO2 molar ratio needs to be close to 3, as previously described.

The product stream consists of a blend of synthetic gas and water, and can be recirculated into the system, immediately after the APOC unit. This serves as an alternative approach to minimize the environmental impact of the entire system and recycle the extracted CO2 in the syngas upgrading process.

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3 CERTIFICATION AND SUSTAINABILITY ASPECTS ANALYSIS

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3.1 Introduction

Within the context of the global energy market, the production and use of biofuels have taken a key role, offering not only a pathway to sustainable development but also a key solution to meet the surging demand for cleaner energy sources. Brazil, renowned for its abundant biodiversity and agricultural expertise, has positioned itself as a significant player in the biofuels' global ecosystem, providing the opportunity of supplying these energy carriers to growing international markets.

In the face of climate change, the European Union (EU) has set specific goals for reducing greenhouse gas emissions and enhancing the share of renewable energy in its energy portfolio. Brazil's expertise in the production of biofuels, presents a compelling solution that addresses the EU's sustainability objectives and promotes the importation of biofuels with a significantly reduced carbon footprint.

Brazil's diverse climate and expansive arable land provide an optimal environment for cultivating feedstocks crucial for advanced biofuel production, such as biogas from agricultural residues and waste materials. The innovative utilization of waste biomass not only mitigates environmental concerns but also positions Brazil as a reliable and efficient supplier capable of meeting the EU's increasing demand for sustainable biofuels.

Moreover, the exportation of advanced biofuels from Brazil holds a distinct advantage in terms of contributing to the EU's decarbonization targets, as the production of biofuels from waste biomass inherently circumvents concerns related to land-use change and competition with food crops, addressing key sustainability criteria set by the EU for imported biofuels. This aligns seamlessly with the EU's commitment to reducing the carbon intensity of its transportation sector, providing a strategic and eco-friendly solution to meet its renewable energy targets.

Nevertheless, for the produced biofuels to be eligible for the mandatory European market, several regulatory requirements must be met, including the system's compliance with carbon intensity thresholds, standards for the used biomass feedstock, specifications for the process energy inputs, among others. These requirements shall also affect the process potential of being certified as a sustainable fuel, which influences its capability of being commercialized in Europe.

Considering the above, the present document seeks to provide key insights to Mele and GIZ in their feasibility analysis of a syncrude production plant from waste biomass sources, presenting a comprehensive understanding of the process characteristics that must be present to align with both regulatory and certification requirements for the exportation of the product to the EU, as well as an overview of the current market status of this kind of fuel.

3.2 Objectives and Scope

3.2.1 Objectives of the service

The consulting service seeks to describe the applicable regulatory framework that affects the development of a syncrude production value chain in Brazil, aiming for the product exportation to the European market. Additionally, it is expected to identify the most suitable certification schemes to be implemented in the syncrude process, considering objective off-taker markets and the client's location, including potential funding opportunities for this kind of projects.

3.2.2 Scope of the service

The regulatory analysis comprises a study of the current European regulations and initiatives that present a direct effect in the syncrude production process, evaluating the design requirements that must be complied for the product to qualify as a commercial sustainable fuel in the European Union.

The certification scheme assessment identifies the currently available certification systems that can be applied to the production of syncrude from biomass sources, prioritizing those that can be implemented in Brazilian territory. Once selected, the certification schemes are classified according with specific criteria to be defined within the report.

Available funding mechanisms for the biomass-based syncrude will be described, including the specific requirements that are needed for the obtention of funding that can affect the process design.

3.3 Process description

3.3.1 General context

As part of the International Hydrogen Ramp-Up Program (H2Uppp), that seeks to promote the implementation of renewable H2 and Power-to-X projects in developing countries, GIZ has engaged, as a public partner, in a public-private cooperation project (PPP) along with the German company Mele, with the objective of developing a syncrude production plant fed by biogenic residues.

The syncrude product is intended to be subsequently exported to the European Union (in particular Germany), as a feedstock for the production of sustainable aviation fuels (SAF), which is expected to progressively replace conventional fossil fuels in the aviation sector. In the definition of its regulatory framework, the EU establishes specific emissions savings requirements for biofuels that must be met for them to contribute to the decarbonization targets of the Member States, and that may determine the way emissions, feedstock and other technical aspects are handled within the productive process. Prior to analyzing the effects of the regulation in the syncrude value chain, it is important to have an understanding of the predefined process to identify the main streams that participate and the potential emissions effluents that may be present. In the following section, the proposed value chain and its potential modifications are described.

3.3.2 Description of potential value chains

The biomethane input required for the synthesis of syncrude is planned to be provided from agricultural residues (specifically pig manure), to then be converted in a steam methane reforming unit into syngas (H2/CO). The carbon content of the syngas is adjusted through the inclusion of an adiabatic reactor that incorporates Topsoe's ReShiftTM technology, reutilizing the carbon dioxide flow obtained from the biogas source. After the previous stage, remaining water and carbon dioxide are removed from the mainstream, which is finally introduced in a Fischer-Tropsch reactor where syncrude is finally synthesized. A simplified diagram of the described value chain can be found below:

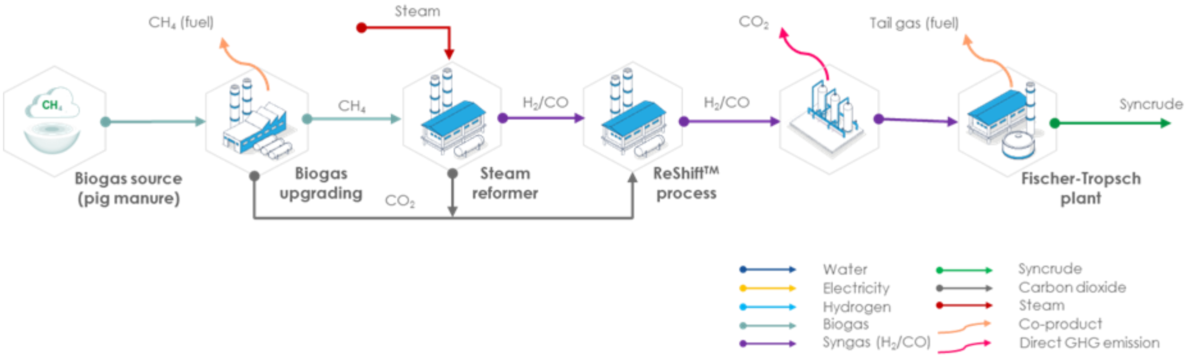

Figure 3-1 Simplified process flow diagram for syncrude production. Source: Hinicio.

Along with the previous design, two additional modifications are being considered to optimize the process yield and integrate output streams. The first variation consists of incorporating a recycle stream that recirculates a fraction of the produced syncrude, feeding the SMR reactor after a pre-treatment process. The other evaluated modification consists in using part of the carbon dioxide emissions from the syngas treatment unit to produce additional carbon monoxide in a reverse water gas shift reactor which would also utilize a renewable hydrogen stream. Both possible additions can be found in the following value chain representation:

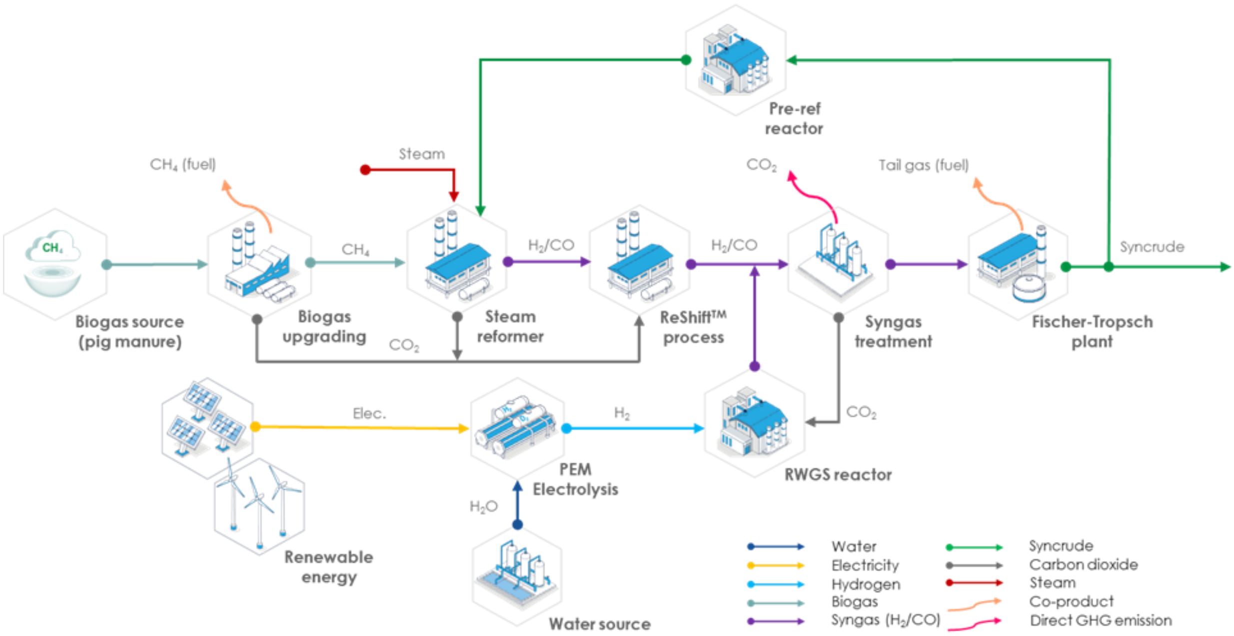

Figure 3-2 Simplified process flow diagram for syncrude production - with modifications. Source: Hinicio.

As will be explained in the next chapter, the inclusion of a renewable hydrogen stream can make a significant impact in the range of regulation that can be applied to the process design, as it has the potential to comply with Renewable Fuel of Non-Biological Origin (RFNBO) guidelines.

3.4 European Union Regulation Assessment

The project being analyzed seeks to generate syncrude from agricultural waste, specifically pig manure, with the intention of exporting it to the European Union for use as a feedstock to produce sustainable aviation fuel (SAF).

The regulations overseeing this project are closely related to the intended applications and the target market of the product. Therefore, this section provides a detailed mapping and analysis of the most relevant regulations, with emphasis on those specific to the European market. These regulations are crucial as they predominantly dictate the requirements imposed on the project.

Firstly, as the organic-origin syncrude will be exported to Europe, it falls under the horizon of Directive (EU) 2018/2001[4] (RED II) for biofuels. Specifically, according to this regulation, the product is classified as advanced biofuel (detailed further in the subsequent chapter), thereby centering on the RED II regulation for this specific advanced product. Additionally, considering the objective of using this product as a feedstock for SAF in Europe, the analysis extends to both European regulations (REFuel aviation EU regulation) and international standards (CORSIA and ASTM D7566) governing this product's use.

If there is an injection of renewable hydrogen in the project, and a desire to enter the RFNBO market with this portion of the syncrude production, it is necessary to comply with the European requirements and standards established for them (Directive (EU) 2018/2001 (RED II) for RFNBO). Hence, a detailed analysis of these regulations is included.

Finally, the regulation under development in Brazil (Projeto de Lei 2308/23) is included as it would directly affect the project due to its geographic location.

3.4.1 Relevant regulation analysis

3.4.1.1 Directive (EU) 2018/2001 – (RED II): Advanced biofuels regulation

Regulatory framework

The Renewable Energy Directive (RED II) determines the mandatory renewable energy consumption objective for each Member State of the EU, setting a minimum share of 32% of renewable energy sources (RES) by 2030. This target will be further increased in the directive's revision (RED III) that updates the minimum share of RES by 2030 to 42.5% (with an indicative target of 45%).

Within the RED II regulation, different definitions of fuels produced from biomass sources are established based on their application and physical form. The definitions presented in the regulation are the following [1]:

- Biomass fuels: Gaseous and solid fuels from biomass sources
- Biofuels: Liquid fuels from biomass used for the transport sector
    - Advanced biofuels: Biofuels made from waste and residues (non-food/feed crop feedstocks[5])
- Bioliquids: Liquid fuels from biomass used for other energy purposes such as electricity, heating and cooling.

For the transport sector, RED III defines a greenhouse gas intensity reduction of 13%, where the contribution of advanced biofuels shall be at least 2.2% by 2030.

[4] Directive (EU) 2018/2001of the European Parliament - also known as the Renewable Energy Directive (REDII) - entered into force in December 2018, as part of the Clean energy for all Europeans package, aimed at maintaining the EU's status as a global leader in renewables and, more broadly, helping it to meet its emissions reduction commitments under the Paris Agreement.

[5] Specific feedstocks under the category of waste and residues can be found in part B of Annex IX of Directive (EU) 2018/2001

Additionally, the production and use of fuels from biomass sources must comply with a respective emissions savings depending on their application. In particular:

- Bioliquids must achieve 70% level of emissions savings[6] compared to a fossil fuel comparator of 183 gCO_2eq/MJ in case they are used for electricity generation, and 80 gCO_2eq/MJ if they are utilized for the production of useful heat;
- Biofuels and biomass fuels must achieve a 65% emissions savings compared to a fossil fuel comparator of 94 gCO_2eq/MJ.

To demonstrate that a given biofuel complies with their required carbon intensity reduction, the emissions associated with its full life-cycle must be calculated through a specific methodology detailed in the RED II regulation.

According with the mentioned methodology, the emissions from the production and use of biofuels can be obtained through three different options [1]:

1. If the emissions from carbon stock changes caused by land-use change are equal or less than zero, default values for the Greenhouse Gases (GHG) emissions savings included in Annex VI of Directive (EU) 2018/2011 can be used directly. The values are defined for different production pathways, where several fuels are associated with a specific feedstock.

2. An actual value[7] can be calculated by introducing the proper factors in the following expression:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} \quad (1)$$

Where:

$E = total\ emissions\ from\ the\ production\ of\ the\ fuel\ before\ energy\ conversion;$
$e_{ec} = emissions\ from\ the\ extraction\ or\ cultivation\ of\ raw\ materials;$
$e_l = annual\ emissions\ from\ carbon\ stock\ changes\ caused\ by\ land\ use\ change;$
$e_p = emissions\ from\ processing;$
$e_{td} = emissions\ from\ transport\ and\ distribution;$
$e_u = emissions\ from\ the\ fuel\ in\ use;$
$e_{sca} = emissions\ savings\ from\ soil\ carbon\ accumulation\ via\ improved\ agricultural\ management;$
$e_{ccs} = emissions\ savings\ from\ CO_2\ capture\ and\ geological\ storage;$
$e_{ccr} = emissions\ savings\ from\ CO_2\ capture\ and\ replacement.$

According with the methodology, all emissions must be reported in units of gCO2/MJ, and they shall be handled through a mass-balance chain of custody. Additionally, emissions associated with the manufacture of machinery and equipment should not be considered.

3. Disaggregated default values listed in Part C of Annex VI of Directive (EU) 2018/2011 can be implemented for some of the factors of the formula from option 2.

For options 2. and 3., once the total emissions from the biofuel value chain are calculated, the respective emissions savings associated with it are calculated as follows:

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[6] This value shall increase to 80% from 2026.

[7] The regulation uses the term "actual value" to refer to the total emissions calculated by using equation (1), instead of the default values included in the RED II annex.

$$Saving = (E_{FT} - E)/E_{FT} \quad (2)$$

Where E_{FT} are the emissions from the respective fossil fuel comparator.

Emissions from the extraction of raw materials (e_{ec}) should include inputs from the following aspects:

- The extraction process
- Collection, drying, transport and storage of raw materials
- Waste and leakages
- Upstream emissions from products utilized in the extraction process

When actual values cannot be obtained, it is allowed to calculate averages based on local farming practices, as well as using official databases such as RenovaBio[8]. Additionally, the regulation itself presents disaggregated values of emissions for different feedstocks depending on their extraction method, which can also be utilized for this input.

The emissions associated with carbon stock changes due to land-use change (e_l) must be included when the biomass sources are provided from feed crops, cultivated over land that previously possessed a high-carbon stock, such as wetlands, forests or peatlands. If the biomass sources come from waste and residues, no emissions from this input shall be considered.

Emissions from processing (e_p) must consider the following items:

- Direct emissions from the process itself (e.g. fuel combustion)
- Waste and leakages
- Upstream emissions of products used in the process
- Upstream emissions from fossil fuels used in the process
- Upstream emissions from the electricity supply

If the electricity supply comes from renewable sources such as solar, wind, geothermal or hydro sources, no emissions shall be considered. In case the electricity is supplied from the grid, average emission intensity values can be used as input.

Emissions from transport and distribution of the fuel (e_{td}) shall include the contribution of emissions released during the ground transportation and shipping of the fuel from the production site to the end-use location. The emissions from the fuel end-use (e_u) are considered to be zero in the case of biofuels and bioliquids.

If soil carbon is proved to be increased from an improved agriculture management, due to crop-rotation, the use of organic soil improves (e.g. compost) or other good practices, associated emissions can be discounted from the total value as part of the (e_{sca}) input.

In a similar manner, emissions avoided due to their carbon capture and storage (e_{ccs}) (that have not been previously included in e_p) can also be removed from the total emissions value. The same applies to carbon emissions that are captured and use as replacement for a carbon source in a process that is otherwise fed by fossil-based carbon input (e_{ccr}).

[8] Instituted by Law 13.576/2017, the Brazilian National Biofuel Policy (RenovaBio) recognizes the strategic role of the biofuels (ethanol, biodiesel, biomethane, biokerosene for aviation and others) in the Brazilian energy matrix with regard to its contribution to energy security, the predictability of market and the mitigation of greenhouse gas emissions (GHG) in the fuel sector.

Besides CO_2, emissions from other GHG gases must be considered, specifically N_2O and CH_4, for which conversion values to CO_2 equivalence shall be implemented based on their Global Warming Potential (GWP) over a 100-year time horizon. These values are shown in the table below:

Table 3-1 CO2 equivalence values for all considered greenhouse gases.

Greenhouse gas	GWP_{100} [gCO_2eq/g]
CO_2	1
N_2O	298
CH_4	25

Another important aspect of the GHG emissions calculation methodology, that must be taken into account, is the allocation of emissions upon the presence of co-products in any given process stage. In case the previous is observed, the emissions up to the analysed process output must be divided between the main product and the rest of co-products in proportion to their energy content, which is defined by their lower heating value in case the co-products do not correspond to excess electricity or heat. No emissions shall be allocated to wastes and residues.

Besides the requirements regarding the handling of the process emissions, additional sustainability criteria for the use of agricultural biomass[9] are outlined, which have the objective of maintaining soil quality and protecting the biodiversity of the territory.

Further elaborating with the above, any biofuel, bioliquid or biomass fuel produced from agricultural biomass (even if they correspond to wastes and residues) can be eligible for contributing towards the RES shares and emissions reduction targets from the EU regulation provided that national authorities have either monitoring or management plans to address the impact on soil quality and soil carbon from the extraction of the biomass source.

Along with the previous, the use of biomass sources shall only be considered for the compliance of the EU decarbonization and RES shares targets if they are extracted from areas that did not have the following status during or before 2008, whether they maintain this status or not:

Primary forest and other wooded land (i.e. native forest where ecological process have not been disturbed and no clear sign of human activity is present)

Forests where a high-biodiversity level has been proven by a relevant competent authority

Areas designated for nature protection purposes; the protection rare, threatened or endangered species or ecosystems

Highly biodiverse grassland that can be considered species-rich by a relevant competent authority

Wetlands (i.e. land that remains covered by water permanently or during a significant part of the year

Peatlands or other land with high-carbon stock

[9] The regulation defines “agricultural biomass” as biomass material coming from agriculture including vegetal and animal substances.

Other requirements for the protection of soil-quality related to the extraction of forest biomass include the implementation of laws that oversee practices of harvesting operation; land regeneration; protection of wetlands and peatlands; among others.

Impact on the process design

To comply with the RED II regulation, the assessed syncrude production process shall achieve a 65% emissions savings compared to a fossil fuel comparator of 94 gCO2/MJ, as in this case, the final end-use of the fuel as feedstock for SAF production and its biomass source coming from pig manure, make it part of the advanced biofuel category.

Considering biogas as the primary feedstock of the process, the emissions associated with the extraction of raw materials ($\mathbf{e_{ec}}$) can be obtained from the disaggregated value of biomethane production from wet manure included in part D. of Annex VI of the Directive (EU) 2018/2011. The specialized tool RenovaCalcTM, within the RenovaBio national program can also be utilized for defining this input.

Given that pig manure is considered a biomass waste source, no emissions associated with carbon stock changes due to land-use changes ($\mathbf{e_l}$) need to be considered in the total emissions calculation.

For the calculation of emissions from processing ($\mathbf{e_p}$), the items detailed in the previous regulatory framework must be evaluated. From the information received in the conceptual design of biogas conversion to syncrude [2] is noted that a fraction of biomethane before the SMR reactor and a tail gas stream from the Fischer-Tropsch process are used as fuel, for which they should be considered as co-products. This is relevant as these streams shall be subject to allocation, reducing the emissions associated to the final product.

From the same conceptual process flow diagram provided by Nirás, a CO2 emission output is released in the syngas treatment stage prior to entering the FT reactor. These emissions should also be counted as part of the $\mathbf{e_p}$ input. Based on the preliminary calculations, it is observed that the inclusion of a renewable hydrogen input and the addition of a RWGS reactor, reduce considerably the contribution of these emissions to the carbon intensity of the product, thus it would represent an advantage for complying with the regulation in case these modifications are implemented.

In case a renewable hydrogen stream is included as part of the process energy inputs, a share of the final product can be considered as RFNBO, provided that the specific requirements from the RED II regulation for this kind of fuels is also complied. The specific conditions for meeting the RFNBO aspects of the RED II regulation will be explained in detailed in a later section.

Considering that the final product is expected to be exported to Europe, the emissions from the shipping of the fuel from Brazil to the final destination must be included in the $\mathbf{e_{td}}$ input. Depending on the transportation mode adopted for the distribution of the fuel from the production plant to the port, additional emissions may also need to be added.

If the biogas feedstock is obtained from the anaerobic digestion of the manure, an emission discount of –45 gCO2/MJ can be included in the total emissions calculation as part of the $\mathbf{e_{sca}}$ input. No emissions from the biofuel end-use ($\mathbf{e_u}$) shall be considered for this specific product.

Finally, it is important to ensure that the sustainability criteria described in the previous section, regarding the protection of soil quality and biodiversity protection is met at the extraction and treatment of biogas from the pig manure source.

3.4.1.2 REFuel Aviation EU

Regulatory framework

The regulation of the European Parliament and of the Council on ensuring a level playing field for sustainable air transport (REFuel Aviation EU), is established as part of the Fit to 55 package that seeks a reduction of GHG emissions in the EU of at least 55% compared to 1990 by 2030.

The REFuel Aviation EU regulation aims to contribute with the previous objective, by setting mandatory targets of SAF distribution to fuel suppliers, to ensure that a minimum percentage of the intake of civil transport aviation comes from synthetic aviation fuel (e-SAF), recycled carbon aviation fuels and aviation biofuels (bio-SAF). For the production of the latter, the regulation excludes the use of food and feed crops as raw materials, limiting the range of eligible feedstocks to wastes and residues; relying on the Directive (EU) 2018/2001 for their definition, aligning with what is described in part B of Annex XI of RED II. Along with the above, the REFuel Aviation EU also obliges to comply with the emissions savings thresholds established by the RED II for synthetic aviation fuels (70%) and aviation biofuels (65%).

The mandatory shares that must be available at civil airports of the EU, will increase progressively from 2025 to 2050, as presented in the following diagram:

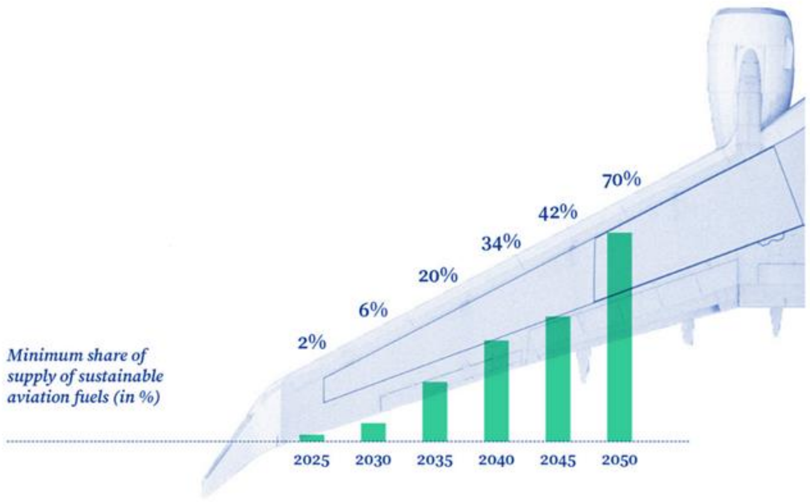

Figure 3-3 Minimum shares of SAF supply at airports from the EU [3]

Besides establishing the minimum shares of SAF that must be available at EU airports up to 2050, the REFuel Aviation EU also includes additional provisions for the effective implementation of SAF as an alternative for aviation fuels. Among these measures, the regulation obliges EU airports to guarantee the presence of specialized infrastructure with the capability of delivering, storing and refuelling SAF.

Additionally, all aircraft operators must ensure that at least 90% of their refuelling takes place within the EU territory, in order to avoid fuel tankering practices, where more fuel than is needed to reach the destination is loaded at places with cheaper prices, which causes the aircraft to carry extra weight, that translates into unnecessary GHG emissions [3].

Impact on the process design

In terms of the syncrude value chain, the REFuel Aviation does not present any major effects on the definition of the process design, besides what it is already established in the RED II regulation. Nevertheless, this regulation provides certainties regarding the future demand of SAF in the EU, as the mandatory shares that will progressively increase within the territory will generate new markets that present an opportunity for the introduction of biomass-based fuels.

3.4.1.3 Carbon Offsetting and Reduction Scheme for International Aviation – (CORSIA)

Regulatory framework

During 2016, the International Civil Aviation Organization (ICAO), put in place this scheme with the objective of achieving a carbon-neutral growth of international flights to avoid the increase of the contribution of the aviation sector in global CO2 emissions. CORSIA (Carbon Offsetting and Reduction Scheme for International Aviation) is one of several measures promoted by ICAO to work towards its aspirational goal of net-zero carbon emissions by 2050, which also include the improvement of aircraft technology and standards, more efficient air traffic management and the development of sustainable aviation fuels [4].

CORSIA works by establishing a baseline defined by the reported emissions of 2019[10]. Each airplane operator (AO), must monitor, report and verify its emissions to each member State, which checks if the CO2 emissions from the AOs remain below the defined baseline (from 2024, the baseline will be defined at 85% of the emissions in 2019). A diagram of the emissions reduction targets from CORSIA can be found in the following diagram:

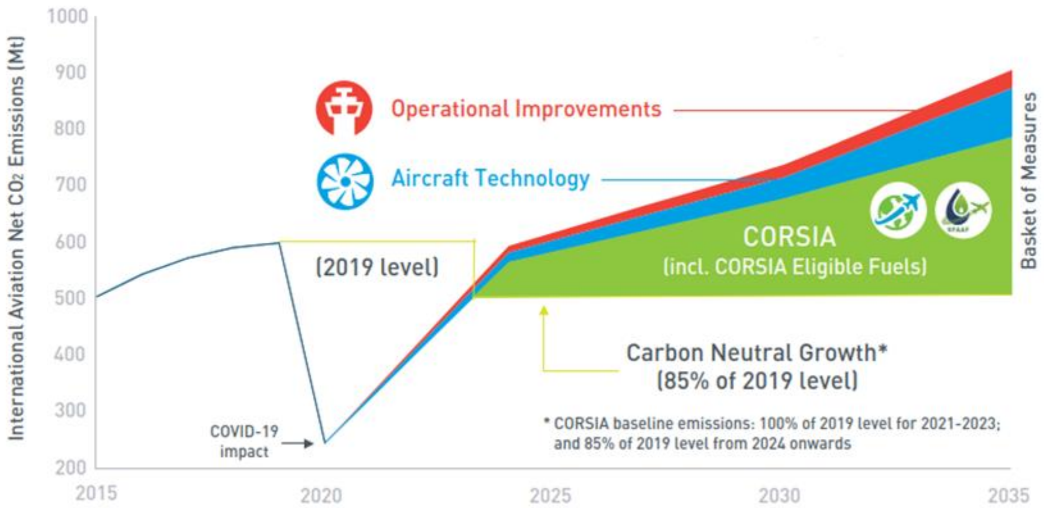

Figure 3-4 CORSIA contribution for reducing CO2 emissions from international flights [4]

In case the baseline is exceeded, offsetting requirements are set for the cancellation of those additional emissions. Member States must ensure the compliance of these offsetting requirements every three years.

[10] Initially the emissions average between 2019 and 2020 was set as the baseline, nevertheless, as the pandemic context affected flights demand during 2020, it was agreed to consider only emissions from 2019.

The offsetting requirements are calculated each year by multiplying the annual CO2 emissions from the AO that are subject to offsetting requirements (emissions savings from the use of sustainable aviation fuels and lower carbon aviation fuels[11] are deducted the final value of CO2 emissions to be offset) and a sectorial growth factor that is calculated by ICAO every year from compiling all data from the member states.

Offsetting requirements are canceled with the purchase of emissions units, which are associated with GHG emissions reduction programs. The emissions units can be traded among member States of CORSIA to facilitate the development of decarbonization measures globally. For an emissions reduction/removal program to be eligible as a source of emissions units, ICAO defines specific criteria that must be met by the programs that share common principles with other certification standards, including [5]:

The emissions unit must come from a GHG emissions reduction or removal that is not part of a business-as-usual activity. The offset must also be permanent and irreversible, and it should not generate an increase in emissions elsewhere.

The quantification of the GHG reduction or removal must be made by comparing the offsetting with a previously determined baseline that represents the emissions that should have taken place without the emissions reduction program. The emissions reductions must be quantified through accurate mechanisms, validated by official protocols and audited by a third-party.

The programs shall demonstrate that they have specific procedures implemented for tracking emissions, avoiding double-counting.

The emissions units program should not have a negative effect over environmental and social aspects of the member State.

The scheme has been implemented in three phases: a pilot phase from 2021 to 2023, a first phase from 2024 to 2026 and a second phase from 2027 to 2035. The participation of States during the pilot and first phase is voluntary, whereas from the second phase, all States with a share of international aviation activity in 2018 over 0.5% of total activity must enforce the compliance of CORSIA to airplane operators (AO) that operate in them [6]. States from Least Developed Countries, Small Island Developing States and Landlocked Developing Countries are exempt of participating in CORSIA unless they decide to be included voluntarily. A map of the status of different States regarding CORSIA can be seen below:

[11] Lower-carbon aviation fuels are only accepted as option until the end of 2023.

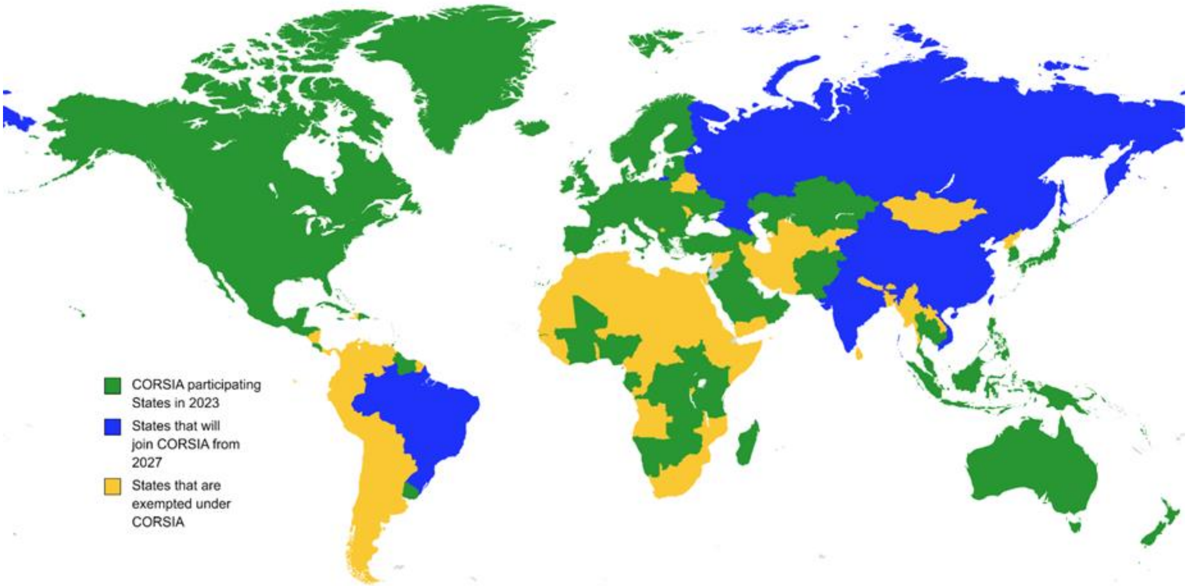

Figure 3-5 Map with the CORSIA status of countries worldwide [6]

All AOs, regardless of their participation in CORSIA, must monitor, record and verify (MRV). CO2 emissions must be monitored using one of the five eligible methods for fuel use measurement. Alternatively, ICAO also allows for the use of its CORSIA CO2 Estimation and Reporting Tool (CERT) which can be accessed from the ICAO Corsia website [4] [4] [4]. The same monitoring method must be implemented throughout the 3-year compliance period.

Only flights that come from or are headed to a member State are subject to offsetting requirements in addition to MRV. This route-based approach is explained in the following diagram:

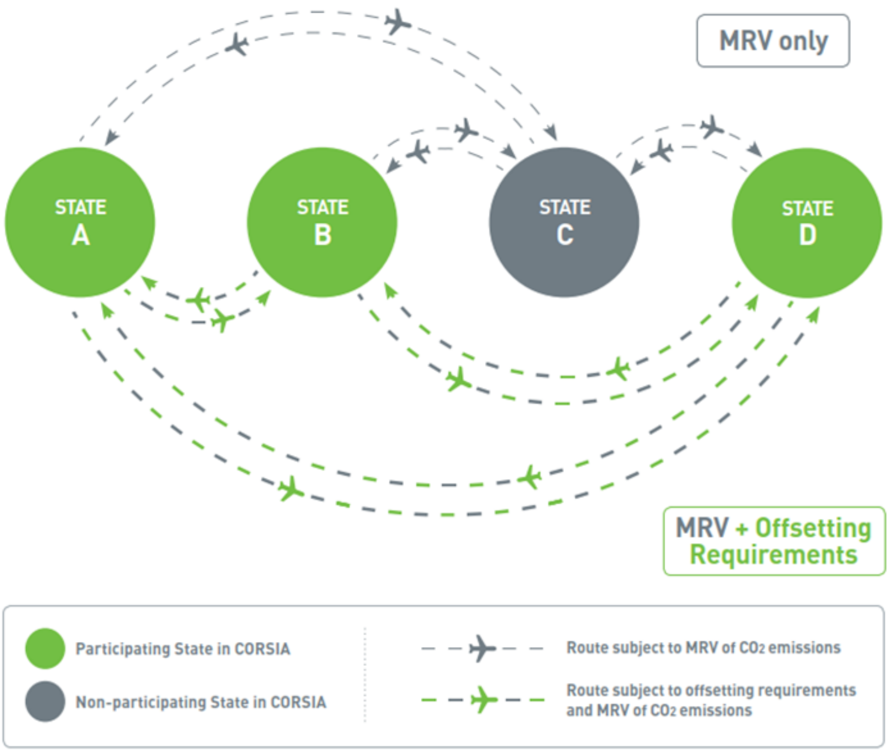

Figure 3-6 CORSIA route-based approach for offsetting requirements definition [4].

As mentioned above, the offsetting requirements are calculated after discounting benefits associated with the use of eligible fuels. To achieve this reduction in the final offsetting requirements value to be canceled through emissions units at the end of the compliance period, the utilized fuels must comply with several sustainability criteria established by ICAO [7]. A summary of these criteria can be found in Annex 1: CORSIA sustainability criteria for sustainable aviation fuel produced by a certified supplier.

Impact on the process design

As presented in Figure 5: Map with the CORSIA status of countries worldwide most States from the EU are participating in CORSIA (or they will be in the next phase), therefore the production and use of SAF that complies with the additional sustainability criteria from CORSIA (besides what is established by RED II) will play a key role in decreasing the offsetting requirements of AOs that must operate between member states of the EU.

While the current process design should not present major challenges in complying with the sustainability criteria as its main feedstock comes from a waste biomass source, a revision of some specific principles should be revised to check potential risks before fixing the process design, especially those that address environmental and social aspects that are not specifically covered by the RED II, such as requirements related to water, air, human and labor rights, social development, etc.

3.4.1.4 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons – (ASTM D7566)

Regulatory framework

At present, the most widely utilized standards for verifying the compliance of conventional jet fuel for its use in aircrafts are the DEF STAN 91-91 (UK Defense Standard) and the ASTM[12] D1655 (Standard Specification for Aviation Turbine Fuels), with the latter setting requirements for several criteria such as composition, volatility, fluidity, combustion, thermal stability, additives, among others [5].

To avoid the need of redesigning engines, aircrafts and fuel delivery systems for the use of sustainable aviation fuels, it is required that these present the same qualities as conventional jet fuel to work as a drop-in replacement; in general, SAF can be loaded into an aircraft up to a blending limit that depends on its chemical composition, which can vary according with its production pathway and the characteristics of the fuel feedstock. Unlike conventional Jet-A or Jet-A1 kerosene, SAF lacks some olefins and aromatics that are needed to a certain level[13] to ensure proper seal swelling used for leaks prevention [8].

The standard that regulates the technical certification of SAF is the ASTM D7566, which defines the specific production pathways that can be used for SAF production and the maximum blending limit for each of them. Once blended with conventional jet fuel, SAF can be regarded as regular turbine fuel under ASTM D1655.

There are currently nine production pathways approved by the ASTM D7566 for SAF production. A summary of their main characteristics, required feedstocks and blending limits can be found in the following table:

Table 3-2 SAF production pathways certified by the ASTM D7566 [8](extracted from [8])

Production pathway	Typical feedstock	Maximum blending limit (%v/v)	Approved on	ASTM Reference
Fischer-Tropsch (FT)	Carbon-based biomass	50%	2009	ASTM D7566 Annex 1
Hydrotreated Ester and Fatty Acids (HEFA)	Oil-based feedstock	50%	2011	ASTM D7566 Annex 2
Synthetized iso-paraffins (SIP)	Lignocellulosic biomass	10%	2014	ASTM D7566 Annex 3
Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics (FT-SKA)	Carbon-based biomass	50%	2015	ASTM D7566 Annex 4
Alcohol (Isobutanol) to Jet (ATJ)	Alcohol or sugar-based feedstock	50%	2016	ASTM D7566 Annex 5
Alcohol (Ethanol) to Jet (ATJ)	Alcohol or sugar-based feedstock	50%	2018	ASTM D7566 Annex 5
Catalytic Hydrothermolysis (CH)	Algae, waste oil, oil plant	50%	2020	ASTM D7566 Annex 6
Hydrocarbon-Hydroprocessed Esters and Fatty Acids (HC-HEFA)	Algae	10%	2020	ASTM D7566 Annex 7
Fats, Oils, and Grease (FOG) Co-processing	Oil-based feedstock	5%	2018	ASTM D1655 Annex A1
Fischer-Tropsch Co-Processing	Carbon-based biomass	5%	2020	ASTM D1655 Annex A1

[12] ASTM: American Society for Testing Materials

[13] Less than 25% as higher percentages are not desirable for internal combustion.

Impact on the process design

Considering that the final goal of the exported product is to serve as feedstock for SAF production, it is important to ensure that the proposed production pathway is included among the certified routes by the ASTM D7566. This aspect should be covered in the case of syncrude as this product is synthesized through a Fischer-Tropsch (FT) process.

Alternatively, a methanol pathway is also being studied as an alternative to syncrude for the product to be exported from Brazil. The subsequent conversion to SAF would need the implementation of a methanol-to-kerosene (MTK) production route. Methanol-to-kerosene technology has been gaining momentum as it has the potential of being less costly than FT, as well as presenting a higher selectivity towards SAF production [9]; additionally, given that methanol can be transported and stored in liquid form, it allows to decouple the production of methanol feedstock from the MTK production plant, whereas the FT route requires for the synthesis of syngas to take place at the same location.

Nevertheless, as shown in Table 3-2, this SAF production pathway has not been certified yet by the ASTM as a valid alternative for aircraft fueling. Moreover, its technology readiness level (TRL) is currently at 4-5 (pilot scale), therefore further development of the technology is required to achieve the ASTM certification. Despite the above, as MTK projects and specialized OEMs continue to increase, this production pathway is expected to receive the ASTM D7566 certification in a short- to medium-term, potentially enabling its industrial implementation at the planned COD of the present export project, nevertheless, the exact dateline for this approval remains unclear as of the completion of the present report.

3.4.1.5 Directive (EU) 2018/2001 – (RED II Art. 25-30): RFNBO regulation

Regulatory Framework

The criteria for ensuring a product's eligibility as a Renewable Fuel of Non Biological Origin (RFNBO) in the European market, are outlined in RED II Art. 25-30 and the two Delegated Acts within the Directive. These criteria primarily focus on two aspects: the CO_2 emissions associated with the process and the requirements for the energy source for H_2 production.

These requirements are relatively complex and among the most demanding on an international level, especially concerning temporal and geographical correlation, as well as the additionality criterion (RED II Art. 25-30). Meeting these criteria may only be justifiable when targeting this specific market and receiving an appropriate premium to offset the associated effort.

In the European RFNBO mandated market, the energy source must be non-biological and renewable. Additionally, to be RED II compliant, it needs to achieve a GHG savings of at least 70% compared to the Fossil Fuel Comparator, defined as 94 gCO_2eq/MJ.

In terms of the energy source, it is not just about its renewable nature but also about meeting specific requirements. In the case where electricity is sourced from the grid, outside of a Power Purchase Agreement (PPA), it must meet the following criteria:

- The electricity is consumed during an imbalance settlement during which power-generating facilities using renewable energy sources were downward redispatched, and the electricity consumed is reducing the need for redispatching by a corresponding amount.

- Consumption takes place in a bidding zone with **more than 90% of RES in the previous calendar year,** and electrolyzer capacity factor does not exceed RES %. Once the 90% threshold is reached, it will be considered fulfilled for 5 years.

On the other hand, if renewable electricity is procured through **one or several Power Purchase Agreements (PPAs)**, the total amount of electricity must be at least equal to the claimed renewable electricity, and must meet the criteria of additionality, geographical correlation and temporal correlation. Alternatively, if the economic operator owning the renewable energy production asset is the same entity producing the fuel, there is no need to establish a Power Purchase Agreement (PPA), but the electricity provided must also comply with these three attributes. The criteria for additionality, geographical correlation, and temporal correlation are described below:

Table 3-3 Attributes required to be recognized as RFNBO under Directive (EU) 2018/2001 – (RED II Art. 25-30) [1] [1]

Attributes for RFNBO	Definition

Additionality	• The renewable electricity plant used to produce hydrogen must have started producing no more than 36 months prior to the electrolyzer Commercial Operation Date.
	  o Exceptions: repowered RES plants when repowering investments exceeds 30% of the original investment.
	• and the installation generating the electricity must not have received CAPEX or OPEX support (unless fully repaid).
	  o Exceptions: support for land and grid connection; and
	
	Projects commissioned before 01.01.2028 will benefit from the transitional rules until 01.01.2038.
	
	The additionality is not required in "bidding zones[14]" where the emission intensity of electricity is below 18 gCO2eq/MJ. Once the 18 gCO2eq/MJ threshold is reached, it will be considered fulfilled for the subsequent five calendar years (after that period, it needs to be demonstrated again).

Geographical correlation	• The electricity from the PPAs is consumed within the same hour by the electrolyzer (from 1.1.20230 onwards; before that, monthly): • or the electricity from the PPAs is stored behind-the-meter within the same hour; • or the electricity from the PPAs is consumed when the clearing price of electricity resulting from single day-ahead market coupling in the "bidding zone", is ≤ 20 €/MWh or ≤ 0,36 x price of an EU CO_2 allowance.
Temporal correlation	• The RES installation and the electrolyzer are in the same "bidding zone" • or the RES installation and the electrolyzer are in neighboring "bidding zones" and the day-ahead price on the RES installation side is equal or higher than the price on the electrolyzer's side. • or the RES installation is in an "offshore bidding zone" interconnected with the "bidding zone" of the electrolyzer.

[14] Geographic zone where market participants (generators and consumers) can exchange energy without re-dispatching (reallocation of generating plant capacity to be produced) [45]

Given that RED II requires a Mass-Balance chain of custody system, it involves accounting for emissions from Well-to-Wheel (up to the point of consumption) and tracking attributes throughout the entire supply chain.

In terms of the participation of RFNBOs in the European market, the RED III[15] regulation establishes specific binding targets for this kind of fuels in the transport and industry sector, with a respective minimum contribution of 2.2% and 50% by 2030.

Regarding the emissions limit of RFNBO production, the RED II regulation establishes a minimum emissions savings threshold of 70% respect to a fossil fuel comparator of 94 gCO_2/MJ, after considering the full lifecycle of the fuel. Equivalent to the GHG emissions calculation of biofuel production, the regulation defines a specific methodology for the measurement of the carbon intensity of the RFNBO, covering its value chain from electricity generation to the end use of the fuel. All details from the methodology for assessing GHG emissions from RFNBO are defined in the Commission Delegated Regulation (EU) 2023/1185, published in February of 2023 [10].

The GHG emissions associated with RFNBOs have to be calculated by the following expression:

$$E = e_i + e_p + e_{td} + e_u - e_{ccs} \quad (3)$$

Where:

$E = total\ emissions\ from\ the\ use\ of\ the\ fuel\ (gCO_2eq/MJ\ fuel)$
$e_i = e_i\ elastic - e_i\ rigid - e_{ex-use} = emissions\ from\ supply\ of\ inputs\ (gCO_2eq/MJ\ fuel)$
$e_i\ elastic = emissions\ from\ elastic\ inputs\ (gCO_2eq/MJ\ fuel)$
$e_i\ rigid = emissions\ from\ rigid\ inputs\ (gCO_2eq/MJ\ fuel)$
$e_i\ ex-use = emissions\ from\ input's\ existing\ end\ use\ or\ fate\ (gCO_2eq/MJ\ fuel)$
$e_p = emissions\ from\ processing\ (gCO_2eq/MJ\ fuel)$
$e_{td} = emissions\ from\ transport\ and\ distribution\ (gCO_2eq/MJ\ fuel)$
$e_u = emissions\ from\ combusting\ the\ fuel\ in\ its\ end\ use\ (gCO_2eq/MJ\ fuel)$
$e_{ccs} = emissions\ from\ savings\ from\ carbon\ capture\ and\ geological\ storage\ (gCO_2eq/MJ\ fuel)$

In a similar manner as the GHG emissions calculation methodology for biofuels, all emissions must be reported in units of gCO_2/MJ. Once the total emissions from the use of the fuel (E) are calculated, the emissions savings of the RFNBO value chain shall be determined using equation (2).

Impact on the process design

(I) Electricity generation criteria

In the context of exporting H_2 to European markets, understanding the concept of the "bidding zone" is crucial, as it relates to specific attributes required by RED II, such as geographical and temporal correlation, and additionality. As of now, there is no consensus or notification from the European Commission on how this concept will be applied to other countries like Brazil.

However, based on the European definition of a Bidding Zone—a geographical area where energy redispatching can be avoided —certain deductions can guide decisions for ensuring that the project is RED II compliance. Redispatch can occur due to congestion in the transmission grid, because of overloads in different elements (lines,

[15] RED III presents updated values from the presented in the RED II regulation.

transformers, etc.). Therefore, **ensuring no power congestion and ample transmission capacity between renewable assets and the electrolyzer could align with the Bidding Zone definition.**

To apply this definition to the Brazilian context, it is essential to analyze the operation of the Brazilian Interconnected System (SIN) and determine when this connection would align with this requirement.

(II) GHG emissions calculation of the process

As mentioned in the previous section, the total emissions from an RFNBO full lifecycle are calculated through equation (3):

$$E = e_i + e_p + e_{td} + e_u - e_{ccs} \quad (3)$$

Delving deeper into the components of the emission calculation formula, it is important to understand how each input applies to the hydrogen value chain to properly determine the total amount of emissions of a specific hydrogen production process.

The emissions from the supply of inputs (e_i) are defined by **elastic and rigid inputs**; and **inputs' existing use or fate**; with the elastic representing those whose supply can be increased to meet additional demand (e.g. renewable electricity). Rigid inputs are more present in recycled carbon fuel production pathways in which, for example, exhaust gases from operating industrial processes are captured and reutilized to produce a fuel.

Emissions from existing use or fate (e_(ex-use)), in turn, refer to CO2 emissions that are avoided after incorporating them into the produced fuel. In the case of hydrogen, the latter emission input is not relevant, however, it can be present when producing other derivatives that require a CO2 source.

Electricity supplied to the electrolysis process that qualifies as renewable according with the requirements previously mentioned, will be considered to have zero GHG emissions. On the contrary, if some of the consumed electricity comes from a grid supply that does not fulfill the requirements to be classified as fully renewable, the carbon intensity associated to this input is calculated as follows [10]:

$$CI_{el} = \frac{e_{gross\_prod}}{E_{net}} \quad (4)$$

Where:

$e_{gross_{prod}} = CO_2\ equivalent\ emissions\ of\ electricity\ from\ the\ grid\ [gCO_2eq]$
$E_{net} = net\ electricity\ production\ [MJ]$

The respective calculations of the two previous factors are determined as presented below:

$$e_{gross\_prod} = \sum_{i=1}^{k} \left(c_{i-ups} - c_{i-combi}\right) \cdot B_i \quad (5)$$

Where:

$c_{i-ups} = upstream\ CO_2\ equivalent\ emissions\ factors\ [gCO_2eq/MJ]$
$c_{i-comb} = CO_2\ equivalent\ emissions\ factors\ from\ fuel\ combustion\ [gCO_2eq/MJ]$
$B_i = fuel\ consumption\ for\ electricity\ generation\ [MJ]$
$i = 1 \ldots k = fuels\ used\ for\ electricity\ production$

Both upstream and fuel combustion emission factors are listed in the emissions calculation methodology defined within the Delegated Act (that complements what it is established in the RED II), including the contribution from non-CO2 gases, more specifically CH4 and NO2, which have to be expressed in terms of CO2eq by using their respective Global Warming Potential over the 100-year time horizon . In the case of electricity produced from the combustion of biomass fuels, CO2 emissions are not considered but CH4 and N2O emissions must be accounted for. The specific values for emissions of other fuels can be found in ANNEX 2: Default upstream and stationary combustion emissions of different fuels (Extracted from [10])

On the other hand, for determining the net electricity production, electrical consumption in the respective power plant and potential pump storage must be discounted from gross electricity generation, as presented in the following expression:

On the other hand, for determining the net electricity production, electrical consumption in the respective power plant and potential pump storage must be discounted from gross electricity generation, as presented in the following expression:

$$E_{net} = E_{gross} - E_{own} - E_{pump} \quad (6)$$

Where:

E_{gross} = $gross\ electricity\ production\ [MJ]$
E_{own} = $internal\ electricity\ production\ in\ power\ plant\ [MJ]$
E_{pump} = $electricity\ for\ pump\ storage\ purposes\ [MJ]$

For the obtention of electricity production and fuel consumption data, the IEA – Energy Statistics Data Browser[16] is recommended as a source for the required data for the calculation of the carbon intensity of electricity consumed from the grid. Official national data sources can also be used provided that they present the same level of detail as the statistics reported by IEA.

Other relevant elastic inputs to be considered in the production of electrolytic hydrogen include:

- upstream emissions from water supply for the electrolyzer operation and cooling requirements,
- emissions originating from electrical consumption and fuel consumption of water intake, treatment, and distribution.

Regarding emissions from processing (e_p), these must include direct emissions from the process itself, waste treatment and leakages. In the case of hydrogen production through electrolysis, this input should not be relevant as no GHG emissions are released in the process.

Emissions related to the transport and distribution (e_{td}) of hydrogen (or other derivatives) should include emissions from the storage and distribution of the end products. This implies the inclusion of emissions associated with the storage, shipping, and transport of hydrogen (or other derivatives) to the final consumption gate.

According to the emissions calculation methodology defined within the Delegated Act, the emissions from combustion of the fuel at its end-use (e_u) are those released by the fuel after its combustion at the final consumption gate. For hydrogen applications, no GHG emissions are presented when combusting or using this gas.

[16] An example for the Brazilian case can be found at: https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=BRAZIL&fuel=Energy%20supply&indicator=ElecGenByFuel

Once the total emissions are determined, the GHG emission savings from the respective RFNBO product in comparison to the defined fossil fuel comparator are calculated as below:

$$Savings = (E_F - E)/E_F \quad (7)$$

Where:

$$E = total\ emissions\ from\ the\ production\ and\ use\ of\ the\ RFNBO$$
$$E_F = total\ emissions\ from\ the\ fossil\ fuel\ comparator\ (94\ gCO_2/MJ)$$

If the savings level reaches the required 70% reduction, the fuel complies with the emission limit to be eligible for the European mandatory RFNBO market.

Another important aspect defined in the emissions calculation methodology within the Delegated Act refers to the allocation of emissions within the electrolysis process. As oxygen is co-produced along hydrogen, emissions up to the electrolyzer output should be allocated between hydrogen and oxygen in cases where oxygen is subsequently used as an input of an additional process or sold in the market. In this case, given that oxygen does not present any energy content, the emissions should be handled through economic allocation.

The economic value to be considered corresponds to the average factory-gate cost of each product over the last three years or, alternatively, it can be estimated from commodity prices (discounting costs from transport and storage). In case oxygen is vented to the atmosphere, all emissions must be allocated to hydrogen.

In case hydrogen is produced by a combination of fully renewable electricity and an additional energy input that does not qualify with the RED II requirements (e.g. electricity from biomass combustion), the share of hydrogen output that can be considered as RFNBO will be determined by dividing the fully renewable energy input by the total relevant energy inputs that enter the process. The aforementioned can also be implemented in case other hydrogen derivatives are produced from a mixture of energy inputs.

(I) Inclusion of a renewable hydrogen input

According with the methodology for GHG emissions calculations described in the Commission Delegated Regulation 2023/1185 (Delegated Acts) [10], the inclusion of a renewable hydrogen stream into the process allows to consider a share of the product as RFNBO, provided that the hydrogen input complies with both the emissions savings threshold and the electricity generation criteria, outlined in the RED II regulation.

To define the share of product that qualifies as RFNBO, the renewable energy inputs that comply with RED II requirements must be divided by the total relevant energy inputs, thus the final share of RFNBO product will be defined proportionally to the energy content from renewable energy inputs that is included in the final product. Other inputs without energy content are only considered for emissions calculation purposes. A graphic representation of this mechanism is presented in the following diagram:

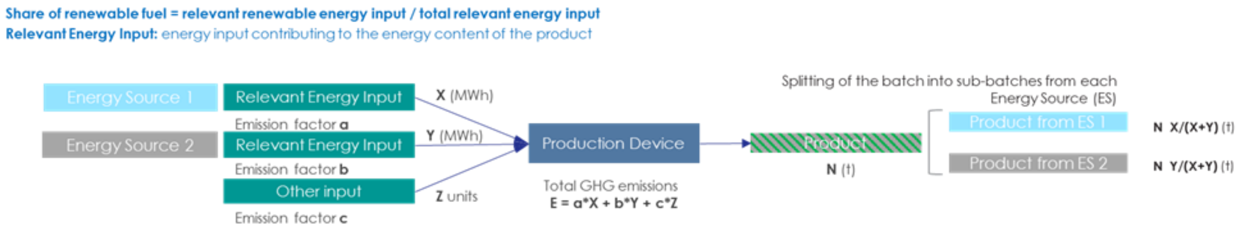

Figure 3-7 Graphic representation of the definition of shares of renewable fuel in a process with multiple relevant energy inputs (Source: Hinicio)

The relevant energy content from material inputs correspond to the lower heating value of the component that is introduced into the molecular structure of the product. For electricity inputs that are supplied to enhance the heating value of the fuel or intermediate products, the relevant energy corresponds to the energy of such electricity.

For the analyzed process, the share of product that will be eligible for the mandatory European market will rely on the contribution from the renewable hydrogen input with respect to the total relevant energy inputs that should also include the hydrogen input from biomass sources.

3.4.1.6 Brazilian bill of law regulating the production of low-carbon hydrogen

Last but not least, it is considered essential to mention the Brazilian Chamber bill that has been proposed and recently succeeded in its initial stage. This bill of law regulates the production of low-carbon hydrogen in Brazil, while simultaneously establishes a voluntary certification system and federal tax incentives. The Bill of law 2308/23 is currently in the process of being submitted to the Senate.

The bill of law proposes that hydrogen should be considered low-carbon if, within the production process lifecycle, its carbon emission results in an initial value equal to or lower than 4 kilograms of carbon dioxide equivalent per kilogram of hydrogen produced (4 kgCO2eq/kgH2). It is expected that this value will need to be progressively reduced starting from December 31, 2030.

Furthermore, the bill of law defines renewable hydrogen as deriving from renewable sources, encompassing solar, wind, hydro, biomass, biogas, biomethane, landfill gas, geothermal, tidal, and oceanic sources. As time progresses, the incentives outlined in the bill of law are intended to gradually shift towards supporting renewable hydrogen (instead of low-carbon hydrogen).

In regards to the production of low-carbon hydrogen and related activities such as processing, treatment, exportation, storage, and commercialization of low-carbon hydrogen, these activities will fall under the jurisdiction of the National Agency of Petroleum, Natural Gas, and Biofuels (ANP). The ANP will be responsible for granting authorization for these activities, with priority given to hydrogen-producing companies in processing these requests [11].

Given that this regulation oversees the production of low-carbon hydrogen in Brazil, close attention needs to be paid to its progress and the requirements it imposes, since it can directly influence in the project.

3.5 Certification systems assessment

3.5.1 Context of the analysis

When determining the certification system for a particular project, it is crucial to begin by identifying the target market for which the system will be utilized. This enables adherence to its specific requirements, facilitating the product commercialization within that market. This approach helps capture the added value of the product effectively.

Within the global framework of emerging low carbon fuels certification, these systems align with diverse motivations depending on the project's intended market. They might encompass voluntary certification -primarily for informational purposes-, or mandatory certification- to meet regulatory standards-. As a result, certificates serve as evidence of adherence to predefined product criteria in both voluntary and mandatory markets, defined as follows (self-defined; Hinicio, 2023):

Voluntary Markets: These markets rely on voluntary information disclosure by their actors, primarily driven by corporate social responsibility (CSR) or marketing purposes. Certificates are used to demonstrate compliance with voluntarily established (non-mandatory/regulatory) requirements, as seen in the Energy Guarantees of Origin (GO) markets for energy in Europe.

Mandatory Markets: These markets use certificates to demonstrate compliance with defined regulatory requirements/standards for the respective geographic market. They aim to ensure legal conformity of products or production processes with the specified standard(s), access potential incentives within legislative frameworks, and receive premium prices for products. In this case, certification systems under regulated markets must mirror the regulations to ensure full compliance with their requirements.

As mentioned in previous chapters, the project under review involves exporting advanced biofuels (such as syncrude or bio-methanol) to the mandatory European market for the production of Sustainable Aviation Fuel (SAF). Hence, it must align with the regulations of this market, obtaining certification under systems recognized by each of the regulations governing it.

When exporting this biofuel to the European market, it is necessary for it to be aligned with various requirements outlined in the RED II Directive (EU) 2018/2001 regulation, which governs biofuels, bioliquids, and biomass consumption within the European Union.

Moreover, considering these biofuels intended use in producing Sustainable Aviation Fuel (SAF), it is crucial to incorporate into the analysis the regulations concerning this end product, as they could significantly impact the upstream project design. The SAF production process should comply with the Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons (ASTM D7566), and if assuming the consumption of SAF within Europe, adherence to the REFuel Aviation EU regulation might also be necessary.

Finally, if the project involves the integration of renewable hydrogen in its production process, the renewable portion of the fuel produced must only align with the RED II Directive (EU) 2018/2001 Art 25-30, that includes specifications for Renewable Fuels of Non-Biological Origin (RFNBOs).

Meanwhile, CORSIA is an additional regulation that might or might not impact the project, depending on the preferences of the off-taker. CORSIA is an international voluntary initiative that establishes various emission targets for operators of aircraft belonging to participating member states, aiming to become mandatory by 2027 in most countries. CORSIA offers various pathways to meet emission targets, with one primary alternative being the utilization of Sustainable Aviation Fuel (SAF) that complies with the sustainability criteria set forth by CORSIA. If the off-takers of the Sustainable Aviation Fuel (SAF) intended for delivery to European countries wish to utilize it as a method for achieving carbon emissions offsetting set by CORSIA, it would additionally be necessary for this product to align with the requirements imposed under this scheme. This applies to both parts of the production: the biofuel that complies with both RED II and REFuel Aviation regulation, as well as the RFNBO portion of the production that fulfills RED II requirements for RFNBO.

The Brazilian law and the standard currently under development in Brazil for low-carbon hydrogen have been included in this report, accompanied by a brief analysis since it is very incipient.

To identify the certification systems applicable to the project according to the aforementioned regulations, an analysis is conducted on existing certification systems globally, in alignment with each of the four applicable regulations.

The certification systems ensuring compliance with the REFuel Aviation EU certification are the same as those for biofuels under RED II, as the latter regulation requires adherence to RED II requirements. Even that the CORSIA and ASTM certification do not need to be acquired before product exportation, and hence might fall beyond the producer's scope, they are included in the analysis as an internal preliminary validation, to ensure subsequent compliance with their requirements and post-export certification of SAF.

3.5.2 Overview of the certification process

The aforementioned regulations that apply to the project require the tracking of attributes throughout the hydrogen supply chain, implementing a Mass Balance chain-of-custody model.

When the Mass Balance model is applied, the certificate must be traded along with the product, and tracking of all economic operators[17] throughout the chain must occur. Below is the detailed process and lifecycle of certificates according to this model.

Firstly, each economic operator (EO) must undergo an initial audit (certification audit), in which - once it is verified that the respective actor complies with the certification system requirements - they receive a certificate from the certification body, based on the corresponding audit (the certificate has a previously determined validity period and is issued for a specific quantity/product per year). A recertification audit is necessary once the initial audit certificate has expired.

Subsequently, each economic operator can issue their respective "Proofs of Sustainability" (PoS), which are statements made by economic operators based on the certificates issued by the certification body, stating the conformity with the requirements of a specific quantity of raw materials or fuels ("batch").

These Sustainability Proofs are used by economic operators to transmit information related to GHG emissions and the batch's sustainability, according to their respective scope in the chain, and are transmitted from one economic operator to another along with the physical product. Therefore, the Sustainability Proof of a downstream economic operator in the production process will consider the previous Sustainability Proof and related emissions. Based on this information, the next economic operator will issue their own Sustainability Proof, ensuring that tracking and certification occur throughout the entire chain.

The Sustainability Proof issued by the last economic operator holds actual value from the consumer perspective as it consolidates information related to the entire chain (all previous steps, in this context). Similarly, those economic

[17] This term refers to a producer of raw material, a collector of waste and residues, an operator of installations processing raw material into final fuels or intermediate products, an operator of installations producing energy (electricity, heating or cooling), or any other operator, including storage facilities or traders that are in physical possession of raw material or fuels, provided that they process information on the sustainability and greenhouse gas emissions saving characteristics of those raw materials or fuels [46].

operators subject to the regulation (e.g., in the case of REfuel aviation regulation, the fuel suppliers) require this final SoP to demonstrate compliance with the regulation, as they contain all the information about a specific volume, allowing for accounting and ensuring compliance with the consumption targets for that product.

3.5.3 Relevant certification analysis

Information was gathered from public sources on various certification systems, and a comparative evaluation was conducted on key aspects of the certification systems that address each of the previous analyzed regulations. This analysis aims to determine the most suitable certification system according to the project needs.

To provide this recommendation, three primary criteria will be assessed: the attributes covered by each certification system, its presence and experience in Brazil (including the existence of certification bodies under the system within the country), and the simplicity of implementation across the entire project.

When conducting attribute analysis, the process involved standardizing the attributes identified in all the certification systems (in order for them to be comparable), and grouping them into 11 categories: GHG reduction and accounting methodology, Feedstock Origin, Biodiversity Conservation, Soil Conservation, Sustainable Water, Air Quality, Community Development, Social Aspects, Labor Conditions, Compliance with Laws and International Treaties, and Continuous Improvement. A definition for each of these categories was established in Annex 3, based on the definitions provided by the RSB certification system, which delves more deeply into its attributes. It is worth noting that the first attribute, related to emission reduction and the emission accounting methodology within certification systems, aligns entirely with the regulation it aims to comply with. Hence, the definitions for these aspects were not reiterated but are explicitly detailed in previous chapters for each regulation.

The following chapters provide a breakdown of the certification systems according to the corresponding regulations. Each chapter covers the systems recognized and approved to certify under each certification or group of certifications. In the analysis were considered only those systems that meet the project's requirements: covering agricultural residues as feedstock (since animal manure is included in this category), encompassing the entire supply chain, and aligning with the geographic area of interest (Brazil for production and Europe for the target market).

3.5.3.1 Directive (EU) 2018/2001 – (RED II): Advanced biofuels and REFuel Aviation EU regulations

The analyzed project focuses on exporting advanced biofuels to Europe, thus being subject to the regulations for biofuels, bioliquids, and biomass fuels under RED II. Additionally, as the product will be used as feedstock for SAF production, ensuring full compliance with the requirements in the European Union upstream of the production point for this type of product is essential. Therefore, the project under study is also required to adhere to the European regulation REFuel Aviation EU. This latter regulation stipulates that SAF must comply with the same requirements as those set by RED II for biofuels, bioliquids, and biomass if produced from organic material, so the certification systems to be analyzed aimed at meeting RED II criteria for this type of products.

Accordingly, the table below provides the details of different certification systems that comply with Directive (EU) 2018/2001 (RED II) for Advanced biofuels, considering only those relevant to the specific project. Systems not covering the project's considered raw material or geographical scope were excluded despite recognition by the European Commission (e.g., BONSUCRO EU certification system exclusively covers sugarcane derivative fuels and TASCC certification system only applies in the United Kingdom [12]).

Table 3-4 RED II (Directive (EU) 2018/2001) certification systems overview

Elements / Certification systems	Type of feedstock covered	Geographic scope	Experience in Brazil (certified projects)	Certification bodies/auditors in Brazil
International Sustainability and Carbon Certification (ISCC EU) [13]; [14]; [15]; [16].	Agricultural biomass, wastes and residues.	Global	Yes. Five (5) projects in Brazil have been certified under this system.	Green Domus, IBD Certificações, SCS global, SGS, Control Union, Dekra, Bureau Beritas, Tuv Rheinald, TUV SUD
Biomass Biofuels voluntary scheme (2BSvs) [17]	Agricultural biomass, wastes and residues.	Global	Yes. Two (2) projects in Brazil.	Bureau Vertias Certification, Control Union
Rountable of Sustainable Biofuels EU RED (RSB EU RED) [18]; [19]	Agricultural biomass, wastes and residues (forest biomass is excluded)	Global	Yes. Only one (1) project in Brazil.	SGS and SCS global
REDcert EU [18] [20]	Agricultural biomass (excluding high-ILUC risk feedstocks), waste and residues	All EU member states and selected countries: Ukraine, Belarus, Norway, Russia and Canada	No	Bureau Veritas, Contol Union Certifications, Dekra, DQS, SGS, Tuv Rheinald, TUV SUD

[18] Although this certification system may not apply to the analysis in terms of geographical scope, it is decided to consider it nonetheless due to its widespread use across Europe, use of auditors with coverage in Brazil and since it is in the process of recognition for the EU RFNBO market.

Four certification systems have been identified and recognized by the European Commission to certify biofuels under the RED II regulation (Directive (EU) 2018/2001): ISCC EU, RSB EU RED, REDCert EU, and 2BSvs.

All of these certification systems encompass hydrogen production derived from agricultural residues within their scope, making the project's feedstock eligible for compliance within these schemes, since it is classified as animal manure and recognized as an agricultural residue. To verify under these schemes the type of raw material used, and its status as a genuine residue, it is required to ensure traceability of the feedstocks back to their origin throughout the entire chain of custody. Each system presents a similar methodology or pathway that need to be followed to ensure these requirements for the feedstock are met. An example of the procedure to guarantee the origin of the feedstock is shown in

ANNEX 3: ASSESSMENT STEPS TO DETERMINE FEEDSTOCK QUALIFICATION UNDER ISCC EU

Simultaneously, they all have a global scope and have certified projects in Brazil under their respective certification systems, except for the REDCert system, which currently covers only a specific list of countries. However, it was included in the analysis because certain auditors operating under this system have a presence in Brazil (so certification for a project in Brazil should not have major complications). Also, this system is in the process of approval for the RFNBO market, which could facilitate implementation if targeting both markets -biofuels and RFNBO- at the same time.

Once the attributes were standardized, identification was made regarding those requirements present in the RED II regulations for biofuels and which attributes were verified by the various certification systems under study (marked with an 'X'). The synthesized information is presented in the table below.

Table 3-5 RED II (Directive (EU) 2018/2001) certification systems attributes analysis [13-20]

Attributes	RED II [1]	ISCC EU [13]	2BSvs [17]	RSB EU RED [18]	REDcert EU [20]
GHG reduction and accounting methodology	X	X	X	X	X
Feedstock origin	X	X	X	X	X
Biodiversity Conservation					
Biodiversity	X	X	X	X	X
High conservation values areas	X	X	X	X	X
Soil Conservation					
Soil protection	X	X	X	X	X
Waste management			X	X	X
Sustainable Water					
Water rights				X	
Water quality				X	X
Efficient use of water				X	
Community Development					
Increase in energy access				X	
Local economic development and employment				X	
Local professional skills training and education				X	
Social aspects					
Human rights				X	
Land right issues				X	

Attributes	RED II [1]	ISCC EU [13]	2BSvs [17]	RSB EU RED [18]	REDcert EU [20]
Labor conditions					
Working conditions / ILO conventions				X	X
Health and safety				X	X
Compliance with Laws and International Treaties		X		X	
Continous improvement		X		X	

From the previous analysis, it can be inferred that the ISCC EU, 2BSvs, and REDCert certification systems primarily demonstrate compliance with the attributes required by RED II, based on CO2 emission requirements and land maintenance and protection, as described in chapter 4.1.1. Some of them also aim to exhibit other attributes, such as water quality in the case of REDCert, although these are considered secondary attributes. Meanwhile, the RSB EU RED certification system integrates numerous extra social and environmental sustainability attributes, encompassing aspects like water usage, air quality, social considerations, human labor, and others. These attributes are inherent to the RSB certification, which are applied across all its certification systems.

While these added attributes might bring benefits by triggering positive social and environmental externalities in Brazil, encompassing important topics in the country such as human and labor rights and air quality, they can also involve significant costs for the project if total compliance is sought. The more attributes required for certification, especially the more stringent they are, the more complex and costly the production of low-carbon/renewable H2 products becomes, widening the price gap with Business as Usual (BaU) options even further. Finally, there is a lot of uncertainty about whether market prices will be sufficient to cover the production costs of these special sustainable products.

However, it is deemed relevant to analyze this system since it has an equivalent for Sustainable Aviation Fuel (SAF) certification. This could once again facilitate a future certification process for this derivative if required, and consequently its entry into the European market.

3.5.3.2 Carbon Offsetting and Reduction Scheme for International Aviation – (CORSIA)

The CORSIA scheme is an initiative aimed at harmonizing international Aviation Fuel requirements. Currently, it operates as a voluntary market but intends to transition to mandatory market at global level starting in 2027.

As previously explained, the necessity to certify this product under CORSIA depends on the preferences of the off-taker to use the productive batch to comply with CORSIA carbon offset targets. Of course, this decision must be accompanied by a decision from the producer regarding entry into this market. Currently, there is a certain level of uncertainty regarding the alignment of requirements for Sustainable Aviation Fuel (SAF) mandated by CORSIA with those the product must also meet in Europe, such as REFuel Aviation standards. Additionally, CORSIA's SAF requirements are stringent in terms of social and environmental sustainability, and as explained before with RSB system, this could potentially imply higher costs and risks from the project's perspective. For this reason, it is deemed crucial to conduct analysis on this aspect and make the decisions before deciding to certify the SAF produced under CORSIA.

The table below summarizes publicly available information presented by both certification systems:

Table 3-6 CORSIA certification systems overview

Elements / Certification systems	Type of feedstock covered	Geographic scope	Scope of attributes	Experience in Brazil	Certification bodies/auditors in Brazil
ISCC CORSIA [21] [21]	Agricultural, forestry, aquaculture and fisheries raw Materials and residues	Global	Under this certification system, there are two accessible certifications: **ISCC CORSIA:** Operators must demonstrate compliance with the two ICAO CORSIA sustainability criteria of greenhouse gases and carbon stock, this latter prohibiting biomass extraction from land with high value content **ISCC CORSIA PLUS:** It additionally includes social and environmental sustainability requirements.	Yes. Four (4) SAF projects certified in Brazil under this scheme	Green Domus, IBD Certificações, SCS global, SGS, Control Union, Dekra, Bureau Beritas, Tuv Rheinald, TUV SUD
RSB CORSIA [22]	Agricultural, forestry and processing residues, and wastes, by-products and co-products.	Global	Under this certification system, there are two accessible certifications: **CORSIA certification only (not RSB):** Operators must demonstrate compliance with the two ICAO CORSIA sustainability criteria (greenhouse gases and carbon stock). **RSB CORSIA certification:** Additionally includes the inherent RSB sustainability criteria.	The certification system has been involved in certifying other products in Brazil, yet there haven't been any SAF projects certified in Brazil under this particular scheme.	Bureau Vertias Certification, Control Union

According to this information, if this regulation becomes mandatory starting in 2027, and the project commences operations after 2024 deciding to enter the CORSIA market, the product should adhere to the latter category and comply with the social and environmental sustainability requirements outlined within it. When analyzing these certification systems, it is observed that both schemes operate similarly: they propose one type of certification based on the basic requirements of CORSIA for eligible fuels and an additional "special" certification for CORSIA sustainable fuels including extra social and environmental sustainability criteria. This aligns with the specifications outlined in the regulation: on one side, the batches of **CORSIA eligible fuel produced before January 1 2024,** have to align only with two sustainability criteria (greenhouse gases requirements and conservation of specific areas with value content); while on the other side, multiple additional social and environmental sustainability attributes are included to batches of **CORSIA sustainable aviation fuel produced after January 1 2024.**

At the same time, both analyzed certification systems cover the project's feedstock and have a global reach, certifying through specific auditors present in Brazil. However, it's noteworthy that only ISCC has conducted SAF project certifications in the country thus far.

For the analysis of the respective attributes, the same approach as in the previous regulation was employed, standardizing the attributes according to the same categories presented, and indicating which of them are present in both the regulation and the certification systems.

Table 3-7 CORSIA certification systems attributes analysis [21-22]

	CORSIA	ISCC CORSIA	RSB CORSIA
GHG reduction and accounting methodology	X	X	X
Feedstock origin	X	X	X
Biodiversity Conservation			
Biodiversity	X+	X+	X+
High conservation values areas	X	X	X
Soil Conservation			
Soil protection	X+	X+	X+
Waste management	X+	X+	X+
Sustainable Water			
Water rights	X+	X+	X+
Water quality	X+	X+	X+
Efficient use of water	X+	X+	X+
Air quality			
Air pollution	X+	X+	X+
Community Development			
Increase in energy access			X+
Local economic development and employment	X+	X+	X+
Local professional skills training and education			X+
Social aspects			
Human rights	X+	X+	X+
Land right issues	X+	X+	X+
Labor conditions			
Working conditions / ILO conventions	X+	X+	X+
Health and safety		X+	X+
Compliance with Laws and International Treaties		X+	X+
Continous improvement		X+	X+

From the presented information, it is evidenced that ISCC offers a modality with fewer requirements, even in the ISCC CORSIA PLUS certification, focusing on criteria mandated by the CORSIA standard. Additionally, this certification system only demands compliance with 3 'MUST' attributes (GHG, high conservation values areas, and biodiversity conservation), while only a 60% of the remaining requirements, labeled as 'MINOR MUSTS,' need to be met. In contrast, the RSB certification system once again encompasses all the inherent requirements within its framework, as also outlined in the RSB biofuel certification system.

Furthermore, under both approaches of ISCC CORSIA certification system, there is a fundamental requirement imposed specifically on agricultural residues (which includes the project's feedstock). It emphasizes that the "use of residues may not occur at the expense of the soil nutrient balance, soil organic matter balance, or important traditional uses (such as fodder, natural fertilizer, material, or local fuel), unless similar or better alternatives are available and applied" [21].

This attribute necessitates a comprehensive analysis concerning the project, particularly if this certification system is selected. For instance, if the biogenic material (such as pig manure) presently serves as a fertilizer or fulfills another specific role within the area, its utilization could potentially impact the project. This situation demands the exploration of alternative methods to address these potential impacts.

Finally, it is crucial to stay informed about how these certification systems and the ones that comply with REFuel aviation regulation, will adapt or integrate in the future according to market evolutions.

3.5.3.3 Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons – (ASTM D7566)

ASTM D7566 stands as the established standard governing the technical certification of SAF (Sustainable Aviation Fuel). It assesses the technologies suitable for producing on-specification neat SAF under specific circumstances and characteristics, certifying them based on its defined requirements and circumstances. Therefore, this standard is the only option available for certifying the project under these international requirements [23].

3.5.3.4 Directive (EU) 2018/2001 – (RED II): RFNBO regulation

Assuming that part of the hydrogen injected into the project is RFNBO compliant, meaning it meets the requirements and implications imposed by RED II (Art. 25-30) described in chapter 4.1.5, certification systems that works under this regulation should be applied. At the moment, there are no certification systems recognized by the European Commission (EC) to certify that a product is compliant with the requirements imposed by RED II for RFNBOs. Nevertheless, three certification system drafts have been identified that are still under EC review (expected to be validated during S1/2024): ISCC RFNBO, REDCert RFNBO, and CertifHy RFNBO. The first two certification systems are adaptations of their biofuel versions, aiming to meet the required criteria for RFNBOs, while the CertifHy system was specifically designed for this market.

Currently, there are no globally certified projects under these systems; they are instead in the process of developing certification pilots. It has been noted that CertifHy also offers a pre-certification process, assessing projects and their alignment with RED II regulations, aiming to address early-stage aspects that do not comply with the objectives, thus reducing risks associated to the project.

The table below summarizes the key aspects of the public information identified for each certification system:

Table 3-8 RED II Art. 25-30 (RFNBO) certification systems breakdown

Elements / Certification systems	Geographic scope	Experience in Brazil (certified projects)	Certification bodies/auditors in Brazil
ISCC EU (extension of the scope to also RFNBOs and RCF) [16]	Only EU	The certification system has been involved in certifying other products in Brazil, yet there haven't been any SAF projects certified in Brazil under this particular schemes.	Green Domus, IBD Certificações, SCS global, SGS, Control Union, Dekra, Bureau Beritas, Tuv Rheinald, TUV SUD
REDcert EU (extension of the scope to also RFNBOs and RCF) [20]	Only EU	No	Bureau Veritas, Contol Union Certifications, Dekra, DQS, SGS, Tuv Rheinald, TUV SUD
CertifHy RFNBO [24]	Only EU. They are starting one pilot outside EU (Omán)	No	TUV SUD and Bureau Veritas

Since it is an emerging market with a high level of uncertainty, due to the constantly evolving regulation and market context, there is not abundant public information about these certification systems. Each system is in process to be recognized by the European Commission with its own designed certification scheme aiming to be pioneer in the market.

Nonetheless, the system boundaries and emission accounting methodologies of these systems must align with the RED II guidelines for RFNBOs to be applicable in this market. Additionally, the minimum attribute requirements must also be included, covering the three key aspects of additionality, geographical, and temporal correlation. At this time, no additional attributes have been identified that are considered by any of these systems, adhering solely to those attributes required by the regulation. Based on available public information, the most significant difference between the components of the presented certification systems, lies in their governance structures and the involved stakeholders.

In terms of regional presence and coverage, all schemes exclusively cover Europe. However, the ISCC system stands out as the sole one that, through its other certification systems (such as those for biofuels and CORSIA), has a presence in Brazil. Nonetheless, all systems engage auditors operating within Brazil, making their implementation in the country less complex. It is noteworthy that, while ISCC is the only system present in Brazil, CertifHy RFNBO may be the most advanced as it is conducting a pilot outside the European Union, validating its attributes and their translation in a different region. This leads to the belief that it could potentially hold greater credibility in certifying RFNBO products at present.

3.5.3.5 Brazilian bill of law regulating the production of low-carbon hydrogen

The Brazilian Chamber bill of law sets out requirements and attributes to be met by producers of low-carbon hydrogen in Brazil, directly impacting the project and its design. This document under Senate analysis also proposes a 'Brazilian standard' to certify low-carbon hydrogen, which will oversee the verification of low-carbon hydrogen production in Brazil, based on the requirements set by the government. This instrument is also the responsible of defining the methodology for greenhouse gas emissions accountability, the production process stages covered by the certification system (certification boundary), criteria for certificate suspension or revocation, information concerning negative emissions, and adaptable mechanisms in cases of temporary hydrogen specification deviations.

Therefore, it is recommended to stay informed and alert to any updates regarding this certification standard, given that the project must be aligned with theses aspects and requirements, ensuring compliance with what defined by the chamber bill.

Furthermore, the regulatory authority is anticipated to create mechanisms for aligning with international hydrogen certification standards and potentially establish guidelines for recognizing certificates issued abroad. Hence, if this certification manages to align with international requirements and even secures recognition from the European Commission under the respective regulations, it might be possible to avoid some of the previously mentioned certifications, and to obtain only one certification that will be equivalent in both markets. This could present an optimal scenario for the project, potentially saving significant resources in the certification processes.

Due to this certification standard being under review with no additional information, no further elaboration is provided at this stage. It is recommended to conduct a more detailed analysis once the standard has been developed and accepted in its entirety.

3.5.3.6 Certification conclusion and recommendations

Deciding on a certification system entails significant complexity, particularly in the face of an uncertain regulatory landscape and project requirements. At this stage of project development, the focus extends beyond mere certification, being essential to prioritize continuous monitoring and deep understanding of the target market regulations that the project aims to engage with.

In this context, evaluating various possibilities and strategies for project certification becomes crucial.

For a product solely targeting the European RED II regulation for advanced biofuels (for biofuels and SAF markets), excluding the CORSIA market, it is advisable to consider certifications that offer simpler requirement frameworks, easing product production and future certification. This approach is recommended because there is no guarantee that there will be a market price that justifies compliance with all the social and environmental sustainability criteria proposed by the more complex certification systems. Systems like ISCC EU, 2BSvs, and REDcert align with this approach. Among these systems, ISCC EU stands out due to its extensive experience and presence in Brazil. Moreover, ISCC EU covers all the regulations analyzed through its diverse certifications, potentially streamlining certification implementation by maintaining consistent interaction with the same institution and stakeholders.

In the event that CORSIA SAF regulations become internationally mandatory, and the producer aims to supply an off-taker looking to enter this CORSIA SAF market, early certification and verification of compliance with the CORSIA requirements become crucial. This guarantees future SAF off-takers that the product could be commercialized in accordance with this international standard. Therefore, utilizing RSB EU certification for advanced biofuels is advisable, since it is the only scheme that allows coverage of additional sustainability criteria similar to those of CORSIA SAF in the project's early stages (before exporting to Europe for SAF production). The RSB EU certification scheme, despite its complexity, is the only scheme that covers biofuels under RED II for advanced biofuels and Aviation REFuel regulation, and also likely facilitates subsequent certification under CORSIA.

However, if CORSIA is not mandatory or its requirements are less stringent, the strategy might lean towards maintaining certifications with minimal demands to reduce certification complexity and associated costs. In such a scenario, ISCC for biofuels could again be advisable due to its regional presence, adaptability to various contexts, and the cross-cutting simplicity it offers across regulations.

In the case the project includes RFNBO requirements for a portion for the fuel to be produced, since the certification systems are even more uncertain, with no certification recognized yet to operate in this market under the RFNBO regulation, the recommendation is way much complex. In this context, ISCC RFNBO stands out for its presence in Brazil and its applicability also in both biofuels and CORSIA markets. However, the possibility that CertifHy might be more advanced and perform better due to its current market evolution requires constant monitoring for a final decision.

Lastly, it is advised to stay informed about the progress and development of both the Brazilian bill of law and the certification standard they are developing, as these could potentially alter the project landscape and the choice of certification systems.

To conclude, the optimal certification strategy heavily relies on regulation evolution and application, as well as the adaptability and scope of different certifications during these changes. Remaining attentive and flexible, closely observing regulatory and market evolutions, is crucial for making informed and strategic certification decisions when necessary.

3.6 Available funding opportunities

A review of available funding opportunities for the development of syncrude production projects was conducted. The review included identifying specific eligibility requirements to obtain approval from respective financial institutions, as well as other potential barriers or recommendations to obtain the funding acquisition.

3.6.1 Overview of the available funding opportunities

For this task, a mapping of potential funding opportunities for biofuels or SAF was conducted, primarily covering two geographical areas: Brazil, recognized as the site for biofuel production, and Europe, as both the site for production and final consumption of SAF.

Throughout the information-gathering process, it became evident that no funding system entirely matched the criteria and conditions of the project. Consequently, a more comprehensive mapping was carried out, encompassing not only applicable funds but also those available in other countries or those that might not entirely align with the project. However, in cases where specific project modifications were required to qualify for the funds (e.g., altering the final product, involving specific partners, or changing the project's target market), this information was included.

Additionally, funds were included regardless of whether they had reached their closing date, since it has been observed that many of these funds consistently reopen for future opportunities. Therefore, it is believed to be crucial to have a clear understanding of those that could remain relevant and stay alert to their updates.

A comprehensive table was created to consolidate information on each funding opportunity, capturing essential data points for the evaluation. This compilation included specific scopes or objectives, application deadlines, and their relevance or compatibility with the analyzed project.

Table 3-9 Fundding opportunities mapped for the project [25-31].

Funding Opportunity	Coverage	Overall budget	Project rate/budget	Opening/ Closing dates	Comments	Mele applicability
Innovation Fund [25] [25]	Funding program supporting projects for the deployment of net-zero and innovative technologies, provided by the revenues of the EU Emissions Trading System.	€40bn (2020-2023)	- 60% of eligible costs (regular grants) - 100% of eligible costs (competitive bidding)	2022/2023	The Innovation Fund focuses on highly innovative technologies and flagship projects within the European Union that can bring about significant emission reductions.	Creating a partnership with bioSAF producer located in the EU would enable application to financial schemes published by the Innovation Fund.
Horizon Europe Framework Programme (HORIZON – CL5-2024-D3) [26] [26]	Development of smart concepts of integrated energy driven bio-refineries for co-production of advanced biofuels, bio-chemicals, and biomaterials.	€7 million	-	September 2024 to January 2025	The programme facilitates collaboration and strengthens the impact of research and innovation in developing, supporting, and implementing EU policies while tackling global challenges. It supports knowledge and technologies.	Applicants eligible for the program include EU and non-EU countries (Brazil not included). A partnership with bioSAF producer located in any of these countries would enable application to the funding.

Funding Opportunity	Coverage	Overall budget	Project rate/budget	Opening/ Closing dates	Comments	Mele applicability
HER+ [27] [27]	Innovation projects leading to CO_2 reduction by 2030. Only for technologies that are eligible under the SDE++. The purpose is to reduce the cost of these technologies further.	€30 million for 2023/2024 round	€6 million max per grant	April 2023 to August 2023 for 2023/2024 round	Combustion and gasification of biomass is an eligible source of renewable energy and qualifies under the HER+. Waste is not yet an eligible source under the SDE++, but this will likely change in 2023/2024.	The funding does not apply directly to the Mele project, but its purpose of reducing costs of technologies could economically affect the development of the project.
TSE Industry Studied tender [28] [28]	For feasibility or environmental study of innovative pilot, industrial demonstration project or fully develop technology that help reduce CO_2 emission before 2030.	€20 million for 2023/2024 round	€2 million max per project	April 2023 / March 2024 (for 2023/2024 round)	Funding for 3 types of studies: feasibility, environmental and similar studies. 6 programs lines available, including other CO_2-reducing measures and hydrogen and green chemistry. Requires a partnership, one of the companies must be able to apply the	The funding is intended only for partnerships with at least 1 Dutch enterprise, thus a partnership with a Dutch company would enable the acquirement of the funding.

Funding Opportunity	Coverage	Overall budget	Project rate/budget	Opening/ Closing dates	Comments	Mele applicability
					results directly.	
DEI+: Hydrogen and Green chemistry [29]	Subsidies for pilot projects, demonstration projects including large-scale demonstration and rollout of innovative technologies for sustainable hydrogen (projects must be new to the Netherlands) and test and experiment infrastructure.	€40 million for 2023/2024 round	€15 million max per project	July 2024/June 2023 (for 2023/2024 round)	Modality: First come first serve. 3 program lines available: Production of hydrogen, Transport and storage of hydrogen carriers and use of hydrogen (carriers) and green electrons	As the subsidy is issued by the Netherlands, a partnership with a Dutch company would enable the acquirement of the funding.
Clean Aviation [30] [30]	Programme driving the energy efficiency and the emissions reduction of future aircraft. Aimed to develop technologies and enablers, leverage essential	EU Funding: €1.7bn Private Funding: >€2.4bn	-	2022: 1st call 2023: 2nd call 2025: Calls for expression of interest may be considered for demo prep/ build phase	The initiative develops two programs (Clean Aviation Programm and Clean Sky 2), both aiming to drive the energy efficiency and the emissions reduction of	The funding is not directly applicable to the project, but it will favour the development of Clean Aviation Fuels such as bioSAF, fostering this market and possible syncrude off-takers.

Funding Opportunity	Coverage	Overall budget	Project rate/budget	Opening/ Closing dates	Comments	Mele applicability
	knowledge and capabilities, and de-risk the identified technologies and solutions, where further maturation, validation and demonstration is required to maximise impact.			2026-2027: Further calls	future aircraft, developing cleaner air transport technologies.	
European Hydrogen Bank [31] [31]	Plan to stimulate and support investments in renewable hydrogen production. This initiative aims to accelerate investment and bridge the investment gap for the EU to reach REPowerEU targets. The plan supports international imports	$800 million	-	November 2023: 1st pilot auction	This initiative is aimed to reach targets of producing domestically 10 million tonnes (mt) of renewable hydrogen by 2030, coupled with 10 mt of imports.	As according to the funding, proposals must be related to projects located in the European Economic Area. A partnership with an off-taker located in the region would enable application for the funding. Nevertheless, the initiative is not operational yet, so further information should be available by the end of the year.

Funding Opportunity	Coverage	Overall budget	Project rate/budget	Opening/ Closing dates	Comments	Mele applicability
	into the EU.					

Despite specific funding schemes targeting hydrogen projects are currently absent in Brazil, a legislative initiative is underway within the Chamber to regulate the production of low-carbon hydrogen. This legislative project is in the process of review by the Senate, proposing a range of fiscal benefits and subsidies specifically aimed at supporting low-carbon hydrogen projects. While this initiative remains at the proposal stage, it is imperative for Mele to remain aware of its progress. Potential incentives resulting from this initiative could significantly enhance the feasibility and viability of the project in the future.

The bill of law extends the tax incentives to companies producing low-carbon hydrogen, granting suspension of the Social Integration Program (PIS), Contribution for Social Security Financing (COFINS), PIS-Importation and COFINS-Importation on the purchase or import of equipment related to hydrogen projects [11]. This benefit can be used for five years, counting from eligibility in the Special Incentive Regime to produce Low Carbon Emission Hydrogen (Rehidro), created by the project. The incentive considers requirements as:

- minimum percentage of use of goods and services of national origin in the production process.
- minimum investment in research, development, and innovation.
- maximum export percentage of the hydrogen produced.

Companies operating in the production of biogas or biomethane for producing low-carbon hydrogen may be considered co-qualified [11].

The conditions outlined for these tax incentives appear to align totally with the current state of the project. This is perceived as a significant opportunity to reduce Mele's tax-related costs, consequently enhancing its financial viability. Leveraging these incentives could greatly improve the project's economic prospects.

Finally, among the identified opportunities in Brazil, the Santander Brazil's 2SC Program has been included. In 2022, this program provided a total financing of R$100 million (Brazilian reais) to the largest biodiesel producers in Brazil, specifically those with expertise in advanced biofuel development, aimed at enhancing these companies' operations.

The program's objective is to strengthen the biological raw materials supply chain for biofuel production, enhancing quality, mitigating risks, and ensuring companies' participation in national and international sustainable fuel markets through certifications.

Regarding this latter point, it is believed that Mele's applicability, focusing on the upstream aspect of the project, could be substantial, since it totally aligns with the advanced fuel production. This could incentivize the development of supply chains based on biological raw materials, aligning with the objectives of this initiative [32].

3.6.2 Funding opportunities recommendations

Regarding syncrude production, although financing schemes were identified, most of them required syncrude production within specific countries, such as the European Union. Therefore, no eligible schemes for the project were identified. A similar situation is observed regarding funding schemes for SAF production. Even that several schemes were identified for this product, none of them applied to the current structure of the project.

However, there are potential alternatives to explore for accessing these funds: forging partnerships with companies from funding-providing countries; establishing a partnership with the off-taker of the syncrude set to produce SAF downstream in the supply chain (located in Europe), to jointly access a financing opportunity from this geography; or to consider producing SAF in the USA or Australia, since these countries present additional funding opportunities, although this option is less favourable due to these countries' potential as low-carbon H2 producers.

In the first option, certain funding programs—primarily originating from the Netherlands—exclusively offer financial support to Dutch companies. Consequently, establishing a strategic alliance with some of these companies is believed to offer a potential alternative for accessing these funds. However, despite this possibility, comprehensive information regarding this option remains elusive. Thus, in case there is interest for this fundings, pursuing an engagement with the entities providing financing becomes imperative to address these uncertainties.

One strategic alternative for SAF production could be to explore partnerships with off-taker companies situated in countries with available financing schemes for SAF. By doing so, Mele could supply renewable feedstock, potentially rendering the entire project eligible under the criteria for selecting these schemes. It is important to emphasize that specific eligibility will largely focus on the criteria unique to each scheme and the chosen pathways for SAF production. In light of this, it is crucial for the project to select an approved SAF production pathway that enhances the probability of eligibility and to submit proposals in collaboration with a local partner to access these potential financing schemes.

A clear final message conveyed by this table is that regions with higher development in the hydrogen industry and its derivatives often have more available financing. This observation provides an encouraging perspective: as the hydrogen industry progresses in Latin America, particularly in Brazil, more opportunities may emerge for the project to access.

Brazil, being one of the leaders in this advancement in South America, is currently in the process of establishing a bill of law that includes tax incentives and subsidies for low-impact environmental hydrogen projects. Being prepared to leverage these incentives and subsidies upon their release by the Brazilian government could present a significant opportunity for Mele. It will be crucial to analyze Mele applicability to these Brazilian opportunities at the opportune moment to maximize their potential.

3.7 Conclusions

Throughout the report, a comprehensive regulatory analysis was performed with a specific focus on the production of syncrude and SAF, with additional key complementary insights regarding the production of methanol, to provide valuable background information to complement the final design of the final process in order to align with the exportation objectives and off-taker requirements.

The previous analysis was then used as an input to identify and select the most appropriate certification schemes that could potentially be implemented to ensure the commercialization of the final product in the European Market. The certification assessment included details about the sustainability criteria that are added to the regulation guidelines and strategy proposals for the best route forward in terms of certification, depending on the intentions of both the client and its respective off-taker.

As an additional complement to the two previous stages of the study, a thorough mapping of potential funding opportunities that could be used for the development of the project was performed, delivering relevant recommendations based on Hinicio's expertise on the subject.

In the following section the main conclusions from each analysis of the present report are summarized:

(I) – Regulatory Analysis

1. Regardless of the choice of producing syncrude or methanol, as both products would obtain their main feedstock from a waste biomass source, the specific emissions savings established by the RED II for advanced biofuels must be met to be eligible for the European mandatory market, following the specific methodology for GHG emissions calculations.

2. The European Union will mandate progressively larger shares of SAF distribution for aircraft operators within its territory, which will increase the demand for this kind of fuel, which will always require to meet RED II sustainability requirements, providing an opportunity for feedstock suppliers that can operate most of the fuel value chain next to renewable energy sources.

3. To generate a carbon-neutral growth of emissions from the aviation sector, the member States of the EU are participating in the CORSIA initiative that will provide additional sustainability requirements for the production of SAF that could have an effect in the Power-to-X project to be implemented in Brazil. As a clearer definition of the different location of the components of the value chain is established, these sustainability criteria will have to be verified to ensure that the final use of SAF will contribute to decrease the offsetting requirements of the European AOs.

4. In case methanol is defined as the export product to be fed into a SAF production process, it will be necessary to understand the status of the MTK production pathway in terms of its certification within the ASTM D7566. As the syncrude option would apply a Fischer-Tropsch process, which is included in the ASTM certification, this feedstock could be immediately used for SAF production.

5. If an additional renewable hydrogen stream is introduced to the process to adjust the H_2:CO ratio from the biomass-based syngas, a fraction of the final product could be labeled as RFNBO, provided that the RED II criteria regarding emissions and electricity generation for these fuels are complied. The obtention of RFNBO product could facilitate the commercialization as a higher demand is expected for this kind of fuels, which should also be commercialized at a premium price.

6. Lastly, at the moment, it seems that the emissions threshold in the Brazilian law under process would not impact the project, as the European market for biofuels and RFNBO is more stringent, thus meeting both criteria. However, it is crucial to continue monitoring the evolution of this law as it might impose a different emission calculation methodology or additional requirements that could affect the project.

(II) – Certification assessment

Regarding the implementation of certification systems in the project, it is the crucial the resolution of regulatory uncertainty and project requisites. Once this is established, the decision-making process on certifications can proceed.

Therefore, it is recommended to prioritize ongoing surveillance and comprehensive comprehension of regulations in the target market.

Additionally, considering the existence of various target markets, the recommendations regarding certification are addressed separately before proceeding to a suggestion that aligns all these considerations:

1. For compliance with the European RED II Regulation, it is advisable to consider certifications with streamlined frameworks to ease certification implementation while meeting project requirements, reducing costs, and mitigating risks. Key recommended schemes include ISCC EU, 2BSvs, REDcert, emphasizing simplified approaches. Notably, ISCC EU stands out due to its extensive experience and a strong presence in Brazil.

2. In case of potential entry into the CORSIA SAF Market, emphasize early certification (considering regulatory requirements for syncrude production) and thorough compliance verification. RSB EU for biofuels is recommended as it allows preliminary coverage aligning with CORSIA SAF criteria, so once exported, it would facilitate the certification under RSB CORSIA for SAF production. If not aiming to comply with CORSIA, leveraging certifications with minimal demands is suggested, continuing with ISCC for biofuels due to its simplicity and regional adaptability.

3. Considering the uncertainty in RFNBO market, with no recognized certification to operate under it, potential candidates are ISCC RFNBO and CertifHy. In this scenario, if certifying the biofuel with ISCC, a beneficial strategy could be to also implement ISCC RFNBO for the RFNBO part of the product. This approach might deliver implementation simplicity and even cost reduction by identifying synergies (e.g., audits) and minimizing initial costs.

4. Lastly, closely monitor developments in the Brazilian bill of law and emerging certification standards is recommended. Although this certification will be voluntary, it potentially offers implementation simplicity for producers in the country, with direct contact and certification tailored to the Brazilian context. Nonetheless, its evolution and recognition by the European Commission for entry into the biofuels and/or RFNBO market need evaluation to determine its suitability for the project (if not mandatory).

The optimal strategy hinges on adaptability to regulatory changes and certification requirements, emphasizing flexibility, vigilance, and well-informed decision-making amidst evolving regulatory landscapes and market conditions.

(III) – Available funding opportunities

1. No funding opportunities were identified that entirely match the value chain or countries where the project will take place.

2. Exploration of alternatives to access funds: forging partnerships with companies from funding-providing countries, partnering with off-takers for syncrude production downstream (located in Europe), or considering SAF production in the USA or Australia despite less favorable conditions due to their potential as low-carbon H_2 producers.

3. Certain funding programs, primarily from the Netherlands, exclusively support Dutch companies, suggesting potential alternative routes through strategic alliances. However, detailed information on this option is limited, requiring engagement with these funding entities to address uncertainties.

4. Exploring partnerships with off-takers in the country in which the SAF will be produced could make Mele eligible for European programs.

5. Regions with advanced hydrogen industry development offer more financing opportunities, indicating future prospects as Latin America, notably Brazil, advances in the hydrogen sector.

6. Brazil's ongoing bill of law includes tax incentives and subsidies for low-impact environmental hydrogen projects, representing a potential opportunity for Mele. Analyzing applicability and readiness to leverage these incentives upon their release will be crucial for maximizing their potential.

3.8 References

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4 ANALYSIS OF THE SOCIO-ENVIRONMENTAL IMPLICATIONS AND REQUIREMENTS FOR SYSTEM REGULARITY

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4.1 Contextualization

This report deals with the "Analysis of Socio-environmental Implications - Requirements for the Regularity of the Rural Sanitation, Bioenergy, Biofuels and H2V Program - Green Fuels Paraná".

This is the product developed by the specialized technical consultancy within the scope of the "DKTI - German-Brazilian Technological Alliance - Action Line 2: Green Hydrogen - Building a Green Hydrogen Economy in Brazil - Technical, Political and Regulatory Framework" Project (Project). This project is the result of Brazil-Germany Bilateral Technical Cooperation, with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and Me-Le Biogás GmbH (Clients) as protagonists on the German side, and the Ministry of Mines and Energy and the Brazilian Energy Research Company on the Brazilian side.

This document includes an analysis of the socio-environmental implications that the facilities linked to the *Green Fuels* Paraná Program will potentially produce and lists the environmental requirements applicable to the proposed projects and the production chain, in the light of current regulations and legislation. It includes an approach to the arrangements and strategies to be applied in socio-environmental licensing processes, with a view to guiding the actors responsible for the system, in its various instances, in obtaining environmental licenses and maintaining the regularity/compliance of the projects over time.

The content presented here is based on the information provided by Me-Le Biocombunstíveis GmbH and the actors involved in the studies, as well as other data and information collected during an *on-site* reconnaissance trip in the municipality of Toledo and the surrounding area in the state of Paraná.
The approach taken here is conceptual and aims to establish a preliminary assessment of the viability of the production systems that are part of the Program in terms of socio-environmental aspects. It also provides guidance for entrepreneurs on the best structural arrangements for environmental regularization and monitoring processes over time .

The main objective of the analyses is to assess the socio-environmental suitability of the Program and determine the formal viability of the projects in the light of current environmental legislation and regulations.

4.2 Characterization of the project

The *Green Fuels* Paraná Program provides for the production of biogas and green hydrogen from the processing of animal waste from large-scale pig, poultry and fish farms established in the western region of the state of Paraná.

The program's configuration includes the construction of rural sanitation systems using underground waste and effluent pipes, connected to 50 biogas and biomethane plants which, in turn, will supply a plant for the production of Syncrude (CnH2n), a liquid product enriched with hydrogen (H2) made from biogas.

The current proposal for the program potentially involves producers from 18 municipalities in the western region of Paraná. Biogas production units are planned to be geographically located in such a way as to allow the effluent to be transported by gravity, considering the insertion of structured network modules in the same micro-basin, connected to biogas plants established at suitable geographical points for receiving the effluent and also in terms of accessibility to access roads and electricity grids.

The system has a modular configuration and provides for various production structures, organized in an organizational chain involving rural producers and industrial, commercial and service structures, as well as providing for the generation and supply of electricity from wind and solar power plants with *off-grid* production (disconnected from the National Energy System). There is also the possibility of using the biogas and biomethane produced to inject surplus energy into the National Integrated System.

For the socio-environmental approach to the Program, in order to facilitate feasibility analyses and the definition of strategies for licensing with regulatory bodies, a non-formal division into two modules was established: 1) Primary Production Module comprising the animal farm enterprises, rural sanitation structures and biogas and biomethane production plant enterprises; and, 2) Syncrude (CnH2n) / Green Hydrogen (H2) Production Module, comprising the biogas transportation pipelines and the Syncrude production plant.

In detail, the so-called Primary Production Module includes the following structures and activities:

a. Agricultural production farms - these are predominantly small and medium-sized rural properties dedicated to multiple production involving livestock and agriculture. In the region where the program is being implemented, pig production is predominant, followed by poultry and dairy farming. Production from psiculture is also significant in the region, and could also be included in the Program due to the effluents derived from this activity. Animal production on farms generates a large amount of excrement, which is currently purified in isolated systems within the properties, which are usually precarious. Today, these systems represent significant environmental impacts, particularly negative ones, as they result in intense and systematic contamination of soils, watercourses and water bodies. Farming activities result in large volumes of liquid and solid waste and effluents, generating significant emissions of methane and other gases flowing out into the open air, which also has a regional impact on air pollution. Another important aspect is that significant volumes of water are used to clean the pig stalls and/or to dilute the excrement in order to take it to the pigsties installed on the farms, when considering the total number of farms in the region. On the farms, the *stakeholders* are usually livestock farmers organized into family structures or small businesses, almost all of which are integrated into large agribusiness cooperatives or companies that process meat, eggs, milk and dairy products.
b. Farm sanitation - the program's proposal for farm sanitation includes the installation of small, watertight reservoirs on farms and rural properties, connected by pipelines to transport effluent to biogas production plants. The pipelines are planned to be built underground using small trenches, which will follow routes predominantly along the right of way of rural roads, mostly in a *layout* favored by gravity, in order to facilitate the conduction of effluents without the use of motor power. However, there is provision for effluent lifting and pumping stations so that there is a constant flow in the system, associated with situations that require overcoming topographical challenges. Each property that is part of the program will have a set of ducts designed to transport effluents (solid and liquid), made of resistant plastic material. There is also a proposal to install electro/electronic cabling in the same trench to interconnect the properties with a digital information, control and communication automation system.
c. Biogas production units - these are industrial units for producing biogas and biomethane and, in some units, also equipped with a system for post-processing the manure used in the biodigester to prepare fertilizers in a composting system. The plants will be production units established in a cooperative system

made up of the rural producers who make up the system module. They will be geographically positioned so that the waste and effluent from a large group of farms is received by gravity, in most cases. Some biogas plants will also be equipped with an energy-generating module, for production to feed the farms or to be sold into the national energy system. The compost and post-processed liquid effluent will be redistributed by road to the agricultural production farms, for use as organic fertilizer to be used on agricultural crops, or for sale in the general trade.

It should be noted that this Primary Production Module in principle consists of dozens of farms interconnected by sanitation structures and linked to a biogas production unit. It is a module that can be replicated in other territories, and 50 similar production modules are planned to be installed in the 18 municipalities that make up the program's region.

The Syncrude Production Module (CnH2n) - Green Hydrogen (H2), will involve an electrolysis plant and the production of Syncrude itself, as well as various structures for transporting biomethane from biogas plants (50 in the program). The following structures and activities are part of the so-called Syncrude Production Module (CnH2n) - Green Hydrogen (H2):

a. Gas pipelines - these are the structures connecting the biogas and methane production units (Module 1) and transporting them to the industrial unit for producing Syncrude (CnH2n) - Green Hydrogen (H2). These will consist of metal pipes and accessory structures (registers, inspection points, etc.). A total of 50 biogas production units are planned for the program, so it can be assumed that there will be 50 interconnection pipelines. These pipelines could certainly be connected to each other along the site, forming branches connected and joined to a central pipeline, depending on the geographical positioning of the plants.

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b. Syncrude Production Unit (CnH2n) - corresponds to the industrial unit for the production of green hydrogen from the electrolysis of water, also considering the addition of a methane reforming process for the production of biohydrogen, as well as the addition of carbon dioxide. Using the Fischer Tropsch method, the chemical/industrial addition process will result in a liquid called Syncrude (CnH_2 n) containing Hydrogen (H_2) in high concentration, suitable for a subsequent distillation process to transform it into a fuel product.

The Syncrude plant will require the supply of energy produced sustainably (wind or solar) and exclusively (*off grid*), since for Green Hydrogen certification, energy obtained from the national system (*on grid*) cannot be counted on.
It is intended that Syncrude will be distributed for subsequent distillation and consumption, using road, rail or waterway transportation (including international transportation by ship). Therefore, the system will also include energy supply and transportation structures, considered in this work as peripheral, not included in the analysis of environmental rites in this report.

Therefore, it should be noted that the work presented here does not deal with the structures and processes related to transportation and logistics after the production of CnH2n and H2, nor does it deal with the externalities of the system such as the supply of electricity needed to run the industrial unit.
In Figure 4-1 below is a schematic or infographic that provides an overview of the production system envisaged for the Program, taking into account the Modules described above.

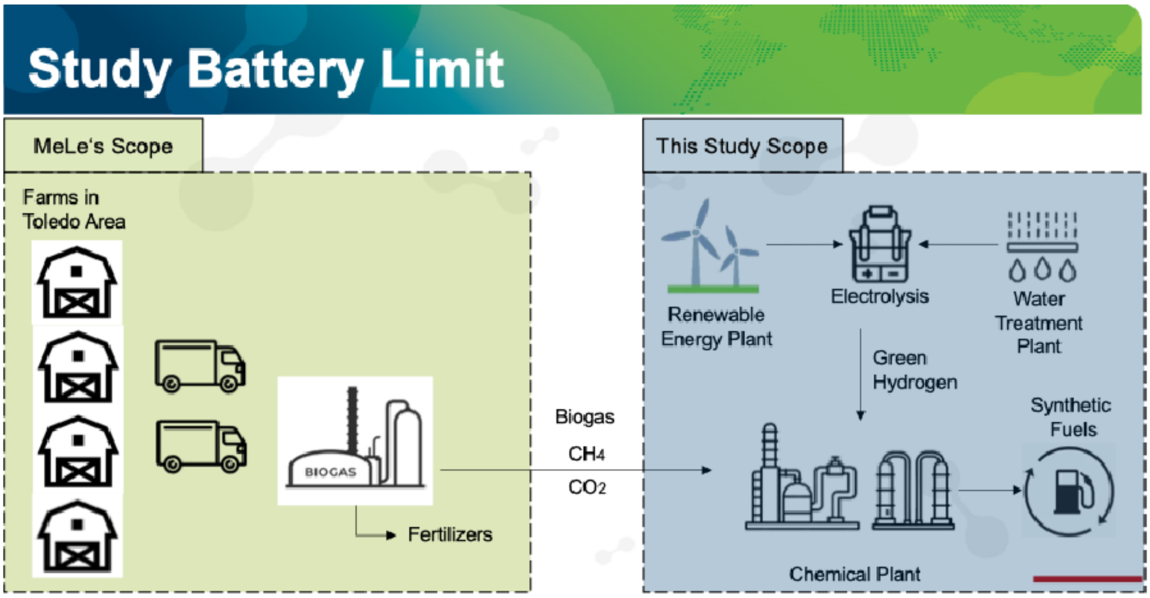

Figure 4-1 Graphical representation of the production modules planned for the Rural Sanitation, Bioenergy, Biofuels and H2V - Green Fuels Paraná Program. Source: NIRAS, 2024.

4.2.1 Scope of the environmental study

The scope of the studies presented here refers to three specific approaches, as follows.

4.2.1.1 Territorial Scope

The program is designed to be applied in the western region of the state of Paraná, with the municipality of Toledo as its territorial hub, although 18 municipalities are expected to be involved.

Considering that most of the projects that make up the Program will be established in state territory, in principle, the rules applicable to licensing and regularity will be state and municipal. However, it is understood that projects included in the Program that may have a potential direct impact on the Paraná River basin, or even on basins bordering the territory of Paraná with other states of the federation, may have to comply with federal licensing requirements established by IBAMA. The requirement for federal licensing will certainly depend on the size (polluting potential) and geographical position of the project.

4.2.1.2 Technical Scope

As far as the technical scope is concerned, the studies are restricted to socio-environmental issues directly related to the licensing, monitoring and regularity regulations of the projects that are part of the Program. In other words, the analyses developed/demonstrated here are limited to the aspects relevant to licensing and regularity, and do not establish larger or more extensive scope relating to assessments of quality of life, accessibility, economic and structural development, analytical projections on environmental improvements derived from the operation of the Program, or similar.

The analyses carried out do not address other issues also related to the environment and society, but which are not pertinent to the current moment, such as ESG standards to be implemented in the projects, carbon balances, greenhouse gas (GHG) emissions, land and environmental regularity (SIGEF/CAR/SISCAR), among others not related to the purposes of the work.

Important additions and developments could certainly be made at a more opportune time in the future, which could represent significant results, with gains and compensations derived from the possible implementation of sustainability solutions, adaptation to climate change and optimization mechanisms that cannot be verified at the moment.

4.2.1.3 Structural scope relative to the model of the enterprise

As for the structural scope, considering the modules presented above, the analyses presented here include the projects, structures and systems directly related to the biogas, biomethane and syncrude production chain.

Therefore, it should be noted that the studies presented here have not analyzed the licensing, monitoring and regularities of peripheral elements necessary for the system to function, such as: power plants, dams and water treatment plants for supplying the system, highways and access roads, power transmission lines, specific transport and logistics systems (road fleets, railway or waterway lines and fleets), among other similar ones. These approaches should only take place when the Terms of Reference are presented, aimed at guiding the entrepreneurs through the process and documentation required for the licenses normally issued by the environmental management bodies.

4.3 Legal aspects related to the project

The approach to legal aspects in this paper aims to present the set of rules and regulations to be followed for the purposes of licensing and the socio-environmental regularity of the project. The aim is to clarify the main elements of the legal framework of the Green Fuels Paraná Program, considering all the licensing phases, for each of the structures or undertakings included in the system.

It should be noted that the provisions of this report do not exhaust the spectrum of legal norms and rules that can be applied to the projects, considering that many of the activities envisaged in the Program do not have specific applicable regulations (for example, rural sanitation networks or the manufacture of Syncrude (CnH2n)), or considering that each municipality has rules that are often different and not homogeneous with regard to the socio-environmental approach.

These regulatory gaps will certainly be worked on over time, even with the contribution of the current developers in conjunction with the teams from the Paraná Water and Land Institute, with the aim of establishing guidelines and parameters for licensing.

In summary, since there is a specific report on legal aspects developed within the scope of this work and signed by an expert lawyer, the main normative and legal elements applicable to the Program are listed below.

4.3.1 Federal approach - applicable legislation

Article 225 of the 1988 Federal Constitution states that "*the public authorities and the community have a duty to defend and preserve the environment, thus establishing that there must be means of protecting and preserving the environment, either at the disposal of the public authorities or at the disposal of the community*."

Therefore, at the constitutional level, art. 225 of the Constitution of the Republic establishes the legal basis for the government's responsibility for environmental protection in the country. The historical sequence of application of the then new Constitution, in addition to the legislation already in force at the time, resulted in various normative and management instruments that culminated in the implementation of rites for the licensing of potentially polluting activities or those with a significant environmental impact.

In Table 3.1 below is a list of the main legal environmental references, at federal level, applicable to projects for the production, treatment and transportation of hydrocarbons by pipelines.

Table 4-1 Summary of environmental legal aspects at federal level related to the project.

LEGISLATION	DESCRIPTION
Law No. 5.197, of January 3, 1967	Provides for the protection of fauna and other measures.
Law No. 6.938, of August 31, 1981	Provides for the National Environmental Policy, its purposes and mechanisms of formulation and application, and makes other provisions.
Law No. 9.433, of January 8, 1997	Establishes the National Water Resources Policy, creates the National Water Resources Management System, regulates item XIX of art. 21 of the Federal Constitution, and amends art. 1 of Law No. 8,001, of March 13, 1990, which amended Law No. 7,990, of December 28, 1989.
Federal Law No. 9.605/1998	Provides for criminal and administrative sanctions arising from conduct and activities harmful to the environment, and makes other provisions.
Law No. 9.795 of April 27, 1999	Provides for environmental education, institutes the National Environmental Education Policy and makes other provisions.
Federal Law No. 12.187/2009	Establishes the National Policy on Climate Change - PNMC and makes other provisions.
Federal Law No. 10.257/2001	Regulates articles 182 and 183 of the Federal Constitution, establishes general guidelines for urban policy and makes other provisions. (City Statute)
Law No. 12.651, of May 25, 2012.	Provides for the protection of native vegetation; amends Laws Nos. 6.938, of August 31, 1981, 9.393, of December 19, 1996, and 11.428, of December 22, 2006; repeals Laws Nos. 4.771, of September 15, 1965, and 7.754, of April 14, 1989, and Provisional Measure No. 2.166-67, of August 24, 2001; and makes other provisions.
Law No. 14.119, of January 13, 2021	Establishes the National Policy for Payment for Environmental Services; and amends Laws No. 8.212, of July 24, 1991, 8.629, of February 25, 1993, and 6.015, of December 31, 1973, to adapt them to the new policy.
Law No. 11.445 of January 5, 2007	Establishes national guidelines for basic sanitation; amends Laws Nos. 6.766, of December 19, 1979, 8.036, of May 11, 1990, 8.666, of June 21, 1993, 8.987, of February 13, 1995; repeals Law No. 6.528, of May 11, 1978; and makes other provisions.
Law No. 12.305 of August 2, 2010	Establishes the National Solid Waste Policy; amends Law No. 9.605, of February 12, 1998; and makes other provisions
Decree 7.830, of October 17, 2012	Provides for the Rural Environmental Registry System, the Rural Environmental Registry, establishes general rules for the Environmental Regularization Programs, dealt with in Law No. 12.651, of 25 October. of May 2012, and makes other provisions

LEGISLATION	DESCRIPTION
CONAMA Resolution No. 001 of January 23, 1986	Provides for basic criteria and general guidelines for environmental impact assessment
CONAMA Resolution No. 002/1994	Defines primary vegetation formations and successional stages of secondary vegetation, in order to guide licensing procedures for the exploitation of native vegetation in Paraná.
CONAMA Resolution No. 005/1988	Provides for the licensing of basic sanitation works
CONAMA Resolution No. 006/1986	Provides for the approval of models for the publication of license applications
CONAMA Resolution No. 237/1997	Regulates the aspects of environmental licensing established in the National Environmental Policy
CONAMA Resolution No. 281/2001	Provides for publication models for license applications
CONAMA Resolution No. 357/2005	Provides for the classification of bodies of water and environmental guidelines for their classification, as well as establishing conditions and standards for the discharge of effluents, and other measures
CONAMA Resolution No. 377/2006.	Provides for simplified environmental licensing of Sanitary Sewage Systems.
CONAMA Resolution No. 397/2008	Amends item II of § 4 and Table X of § 5, both of art. 34 of Resolution No. 357 of the National Environment Council (CONAMA) of 2005, which provides for the classification of bodies of water and environmental guidelines for their classification, as well as establishing the conditions and standards for discharging effluents.
CONAMA Resolution No. 410/2009	Extends the deadline for supplementing the conditions and standards for effluent discharge, provided for in Article 44 of Resolution No. 357, of March 17, 2005, and in Article 3 of Resolution No. 397, of April 3, 2008. Extends the deadline for supplementing the conditions and standards for effluent discharge, provided for in Article 44 of Resolution No. 357, of March 17, 2005, and in Article 3 of Resolution No. 397, of April 3, 2008.
CONAMA Resolution No. 428/2010	Provides, within the scope of environmental licensing, for the authorization of the body responsible for the administration of the Conservation Unit (CU), referred to in § 3 of article 36 of Law No. 9.985 of July 18, 2000, as well as for the science of the body responsible for the administration of the CU in the case of environmental licensing of projects not subject to EIA-RIMA and makes other provisions
CONAMA Resolution No. 430/2011	Provides for effluent discharge conditions and standards, complements and amends Resolution No. 357 of March 17, 2005, of the National Environment Council - CONAMA.
CONAMA Resolution No. 498/2020.	Defines criteria and procedures for the production and application of biosolids in soils, and makes other provisions.

LEGISLATION	DESCRIPTION

Source: Compiled by the author, 2023.

In addition to the legal framework listed above, it is worth mentioning other regulations that could be applied to the Program under analysis, such as the regulations of the National Electric Energy Agency (ANEEL), which regulates the energy sector in Brazil, the National Electric System Operator (ONS), the regulations of the National Petroleum, Natural Gas and Biofuels Agency (ANP), which regulates the production, distribution and use of biomethane as a fuel, the regulations of the National Water Agency (ANA), the regulations of the National Historical and Artistic Heritage Institute (IPHAN), the resolutions of the National Land Transport Agency (ANTT), the ordinances of the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), the guidelines and standards of the Ministry of the Environment (MMA), the resolutions of the National Environment Commission (CONAMA), as well as other federal bodies.

4.3.2 State approach - applicable legislation

Legislation in the state of Paraná basically follows federal legislation on environmental protection and the inclusion of projects in its territory. The main legal provisions are listed in Table 4-2.

Table 4-2

LEGISLATION	DESCRIPTION
Law 21052 - May 23, 2022	It establishes guidelines and criteria for the licensing, implementation, operation and closure of sanitary and industrial landfills and for waste management, including the activities of transport, collection, storage, treatment and destination and final disposal of waste, with a view to controlling pollution, contamination and minimizing their environmental impacts.
Law 21454 - May 3, 2023	Provides for parameters to encourage the use of renewable hydrogen in the state of Paraná.
Decree 11300 - June 3, 2022	Establishes the Paraná State Environmental Education Program and makes other provisions.
Law 20929 - December 17, 2021	Makes environmental compensation mandatory for projects that generate negative environmental impact that cannot be mitigated, within the scope of the state of Paraná.
Law 20607- June 10, 2021	Provides for the Paraná State Solid Waste Plan and other measures.
Law no. 19500 - May 21, 2018	Provides for the State Biogas and Biomethane Policy and adopts other measures.
Law no. 19261 - December 07, 2017	Creates the State Solid Waste Program Paraná Resíduos to comply with the guidelines of the National Solid Waste Policy in the State of Paraná and makes other provisions.
Law no. 18295 - November 10, 2014	Establishment, under the terms of Article 24 of the Federal Constitution, of the Environmental Regularization Program for rural properties, created by Federal Law No. 12,651, of May 25, 2012.

LEGISLATION	DESCRIPTION
Law No. 17279 of August 1, 2012	Establishes the State Technical Register of Activities that Potentially Pollute or Use Natural Resources, part of SISNAMA, as well as the Environmental Inspection Control Fee.
Law 17134, April 25, 2012	Establishes the Payment for Environmental Services, especially those provided by Biodiversity Conservation, which is part of the Bioclima Paraná Program, and provides for Biocredit.
LAW No. 16.346 - December 18, 2009	Provides for the obligation of potentially polluting companies to hire an environmental technician.
Decree no. 3148 - 15/06/2004	Establishes the state policy for the protection of native fauna, its principles, targets, objectives and enforcement mechanisms, defines the state system for the protection of native fauna - SISFAUNA, creates the state council for the protection of fauna - CONFAUNA, implements the state network for the protection of native fauna - REDE PRÓ-FAUNA and makes other provisions.
Law no. 13806 - 30/09/2002	Provides for activities related to air pollution control, standards and air quality management, as specified, and adopts other measures.
Decree 4646 - 31/08/2001	Provides for the granting of rights to use water resources and adopts other measures.
Law No. 12726 - 26/11/1999	Establishes the state water resources policy and adopts other measures.
Law no. 10.066 - 27/07/92	Creates the Secretary of State for the Environment - SEMA, the autonomous entity Environmental Institute of Paraná - IAP and adopts other measures.
Law no. 19500 - May 21, 2018	Provides for the State Biogas and Biomethane Policy and adopts other measures.
Law 20435- December 17, 2020	Establishes the Paraná Rural Renewable Energy Program and makes other provisions.
Decree 7872 - June 9, 2021	Regulates Law 20.435, of December 18, 2020, which established the Paraná Rural Renewable Energy Program and limited the special discount referred to in Law 19.812, of February 6, 2019.
CEMA Resolution 110 - May 04, 2021	Establishing criteria, procedures and typologies for activities, undertakings and works that cause or may cause local environmental impact.
CEMA Resolution 109 - February 09, 2021	Establishes the criteria and procedures for Solid Waste Management in the State of Paraná.
CEMA Resolution 107 - September 9, 2020	Provides for environmental licensing, establishes criteria and procedures to be adopted for activities that pollute, degrade and/or modify the environment and adopts other measures.
CEMA Resolution No. 088 - August 27, 2013	Establishes criteria, procedures and typologies for municipal environmental licensing of activities, works and undertakings that cause or may cause local impact and determines other measures.
CEMA Resolution no. 081 - October 16, 2010	Provides for Ecotoxicity Criteria and Standards for the Control of Liquid Effluents discharged into surface waters in the State of Paraná.

LEGISLATION	DESCRIPTION
CEMA Resolution No. 070 - October 1, 2009	Provides for environmental licensing, establishes conditions and criteria and makes other provisions, for Industrial Enterprises.
SEMA Resolution No. 051 - October 23, 2009	Exemption from State Environmental Licensing and/or Authorization for small enterprises and activities with low environmental impact.
SEMA Resolution No. 021 - of April 22, 2009	Provides for environmental licensing, establishes environmental conditions and standards and other measures for sanitation projects.
SEDEST Resolution 32 - June 3, 2022	Establishes procedures for the integration of environmental licensing and granting procedures for the use of water resources in Paraná.
SEDEST Resolution 15 - March 5, 2020	Establishes conditions and criteria, and adopts other measures, for the environmental licensing of pig farming enterprises in the state of Paraná.

Source: Compiled by the author, 2023.

4.3.3 Municipal approach - applicable legislation

The rules and legislation applicable to the municipalities involved in the Program generally follow state regulations. Some specificities may be found at municipal level, determining differences in the requirements and parameters applicable to the licensing of projects. Normally, more developed municipalities, such as Toledo, located in the study region, have a better environmental service structure and a greater framework of laws and regulations applicable to environmental licensing and compliance. In these cases, there may also be some level of licensing autonomy, delegated by the state. To this end, developments in these municipalities may certainly be required to comply with municipal licensing rites, establishing an additional level of bureaucracy and technical approach to be followed.

Other smaller municipalities certainly don't have the same structure, resulting in state licensing taking precedence, with the municipal procedure boiling down to the entrepreneur obtaining the consent of the Municipal Executive Branch, attesting that the project they intend to implement complies with current regulations, which are normally restricted to urban and rural/agricultural rules.

Normally, when it comes to municipal licensing, it is quite common for it to boil down to authorizations dealing with non-objection to location, suppression of vegetation, disposal of solid waste, accessibility by rural roads and paths and other similar objects.

As these are 18 municipalities included in the Program, the legislation will not be compiled here, although the technical approaches to licensing/regularization applicable at municipal level are provided for in the chapters later in this report.

4.4 Conceptual approach on environmental compliance

In order to fully understand the scenarios and socio-environmental approaches of the Green Fuels Paraná Program, it is important to establish a conceptual basis on the subject, exploring the minimum requirements applicable to the licensing, monitoring and environmental compliance processes of each planned project.

This chapter presents the minimum concepts needed to understand environmental authorizations, licenses and permits, considering their role in making all the components of the entire project viable and compliant.

4.4.1 Environmental licensing instruments

The level of environmental licensing for a project is defined according to its polluting potential, as indicated above. The more complex the licensing processes and requirements are, the greater the potential impact on the environment and the influence on society.

In order to assess and decide on the environmental licenses requested, the existing regulations point to gradual levels of environmental studies and documentation to be submitted when applying to the regulatory bodies. Thus, simple projects with low impact potential will normally be licensed by means of an Environmental Authorization, and in this modality there is not even a requirement for specific environmental studies. Developments with medium impact potential usually require simplified socio-environmental studies and a slightly denser licensing process. On the other hand, large-scale projects or those with a high potential for impact and social influence tend to depend on wide-ranging and detailed socio-environmental studies, with a very complex decision-making process on the part of the regulatory bodies. Licenses for complex projects usually depend on more than one body being involved in the licensing process.

That said, below are the definitions of the main instruments required for deliberating on environmental licensing and granting the use of natural resources.

4.4.2 Environmental permits

According to CEMA Resolution 107/2020, **Environmental Authorization** is the administrative act by which the competent environmental body authorizes the execution of works, activities, research and services of a temporary nature or emergency works, in accordance with the specifications contained in the applications, registrations, plans, programs and/or approved projects, including the environmental control measures and other conditions determined by the competent environmental body.

According to the regulations in force at state level, earthmoving activities over $100m^2$ and the laying of pipe networks require the issuance of Environmental Authorizations.

In the case of the projects that make up the Program, it is expected that the Environmental Authorization instrument will be required for the licensing of farms, the implementation of rural sanitation networks for the transport of waste, water and telecommunications and for the licensing of pipelines for the transport of biogas or biomethane between the production plants and the Syncrude Plant.

In order to install the network of outfalls, it is also necessary to obtain forestry authorization to cut down vegetation if the route reaches areas with native forest cover. The **Forestry Authorization - AF** is the document that authorizes the cutting, suppression and/or use of woody material from native vegetation. In native forest remnants, the installation of pipelines may require both the felling of isolated trees and the suppression of vegetation.

It is worth highlighting possible obstacles in the case of cutting down endangered species, which are fully protected by law, or in the case of suppressing vegetation in a Permanent Preservation Area (APP), which will certainly occur.

Normally, a Forestry Authorization (FA) also defines as a consequence the carrying out of native forest replacement plantations as compensation for the trees cut down by the enterprise. Entrepreneurs will then have to reserve available land to accommodate replacement plantations within the same watershed, which may require the purchase of land or agreements with the owners of integrated farms to accommodate plantations.

The Forestry Authorization is used for undertakings subject to environmental licensing specifically in cases of Public Utility and Social Interest, and it is not permitted to transport the raw material resulting from exploitation without issuing the Authorization for the Use of Raw Material from Forest Products - AUMPF and its respective Document of Forest Origin - DOF. Therefore, in cases where native vegetation that produces usable timber is suppressed, the entrepreneur will also have to comply with the AUMPF and DOF requests in parallel with the AF request.

For the cutting of exotic forest species in APP and replacement of planting with native species, this will be done through full Environmental Licensing by Adhesion and Commitment - LAC, the criteria for which are established in SEDEST Resolution no. 27/2021, under the terms of the caput of article 68 of CEMA Resolution no. 107/2020.

4.4.3 Simplified environmental licenses (LAS)

It is a type of licensing that can be carried out in a single phase. The granting of the Simplified Environmental License (Licença Ambiental Simplificada - LAS) establishes approval of the location and design of the undertaking, activity or work of a small size and/or that has a low polluting/degrading potential, attesting to its environmental viability and establishing the basic requirements and conditions to be met, as well as authorizing its installation and operation in accordance with the specifications contained in the approved requirements, plans, programs and/or projects, including the environmental control measures and other conditions determined by the competent environmental agency.

4.4.4 Environmental licenses full (THREE-PHASE)

The licensing of medium and high potential impact projects is carried out using the instruments of full environmental licenses. The full licensing process normally has three phases that can be applied to projects, hence it is called three-phase.

The licensing of an enterprise begins with the opening of a protocol containing a request to classify the enterprise, accompanied by basic documentation indicating what is intended. Normally, this initial protocol is carried out using forms already available from the licensing authorities.

In response, the regulatory body usually provides guidance on the documentation and studies needed to obtain the socio-environmental licenses, defining which framework applies to the intended project, as well as providing the Terms of Reference that guide the entrepreneur as to the minimum technical demands that must be met for licensing to take place. Therefore, it is at this point that the demands for environmental studies are clarified, including identifying the type of study required by the environmental agency, which may be: Simplified Environmental Study - EAS, Simplified Environmental Report - RAS, Preliminary Environmental Report - RAP; Environmental Control Plan - PCA, Neighborhood Impact Study - EIV, Environmental Impact Study - EIA, Environmental Impact Report - RIMA, Environmental Control Plan - PCA, among others.

It is only after the elements requested by the environmental regulatory body have been produced and provided (by protocol) that the licensing process effectively begins, following all the phases defined in specific rules over time.

A. Prior Licensing (LP)

The Preliminary License (LP) is one of the fundamental pillars of the environmental licensing process, representing the first stage in the evaluation and locational authorization for the projects that make up the system. Prior licensing therefore determines the environmental viability of whether or not the project can be established in the geographical location planned by the entrepreneur.

The primary objective of the Preliminary License is to carry out a general assessment of the proposed project, seeking to identify possible environmental impacts that may occur as a result of its installation and operation, analyzing these aspects in relation to the geographical location where the structures are to be located.

According to Article 72 of CEMA Resolution 107/2020, the LP, which is required for projects with the potential to have an impact on the environment, must be requested at the initial planning stage. The main objectives of this license are: to approve the location and design of the project, to certify its environmental viability, to establish basic requirements and conditions for the subsequent phases of implementation, including limits for the discharge of effluents, waste and emissions, according to the area and type of project, and to request proposals for environmental control measures in view of the impacts expected during the implementation of the project.

At the end of this process, the environmental authority can grant or deny the Preliminary License. If granted, this license establishes the guidelines and conditions that the entrepreneur must follow in the next phases of licensing. These conditions are essential to ensure that the project is developed in such a way as to minimize its environmental and social impacts, as well as meeting the applicable legal and technical requirements.

The socio-environmental studies required at this stage depend on how they fit in with the rules in force and also on guidance from the licensing body. Normally, the standards already define frameworks based on the potential impact (or polluting potential, in some cases) linked to the type of activity that will be developed, as well as the size and geographical location.

B. Installation License (LI)

This phase of the licensing process involves assessing the structures and processes involved in the intended project. At this stage, the environmental studies must present plans for controlling, monitoring, mitigating and remedying the impacts to be implemented during the installation of the project.

The main objective of the implementation licensing process is to check that the executive projects are in line with what was approved in the previous phase, including environmental control plans, waste management and mitigation measures. Its purpose is also to assess whether the structures and systems will be detailed enough for the management bodies to fully understand the project and whether they will comply with the regulations in force in all instances, in a comprehensive and safe manner.

At this point, detailed projects must be submitted to the licensing body, with dimensions and volumes not only for the project's construction works, but also for its operation, in order to provide an understanding of the social and environmental risks inherent to it. At this stage, analysts from the regulatory agencies establish a solid assessment of the implications that the project will have on society and the environment during its construction and operation, determining conditions and measures to be complied with in order to minimize negative impacts and enhance the positive impacts resulting from the project.

According to Article 81 of CEMA Resolution 107/2020, the LI is required as soon as the executive projects for the enterprise, activity or work have been drawn up and must contain a projection of the environmental control measures.

The Implementation License authorizes the construction/building of the project's facilities and structures, but does not allow it to operate.

C. Operating License (LO)

The Operating License (LO) is the final stage of environmental licensing, authorizing the start of regular operating activities for the project, which at this stage has already been built. Its primary purpose is to ensure that the project operates in compliance with environmental standards, respecting legal norms and minimizing its impacts. This phase involves detailed checks to ensure the effective implementation of environmental control and compensation systems.

The LO is a formal authorization to operate, something similar to an operating permit applied to environmental issues.

The granting of the LO may include specific conditions established by the environmental authority to ensure that the project's operations proceed in a sustainable and environmentally appropriate manner. Obtaining the LO, however, is not static; periodic assessments are carried out to verify ongoing compliance with the conditions and renewal is subject to continued compliance with environmental standards.

4.4.5 Water resource concessions

The Grant is the administrative act that expresses the terms and conditions under which the Government allows the use of water resources for a specified period. According to Law 12726/1999, it is aimed at meeting social interests and its purpose is to ensure quantitative and qualitative control of water use and to regulate the exercise of rights of access to water.
Depending on the characteristics of the project, it may require a permit or registration of insignificant water use. In addition to water grants and registration of insignificant water use, there is also prior approval for drilling wells. A Figure 4-2 below shows the different types of authorizations by type of source and use.

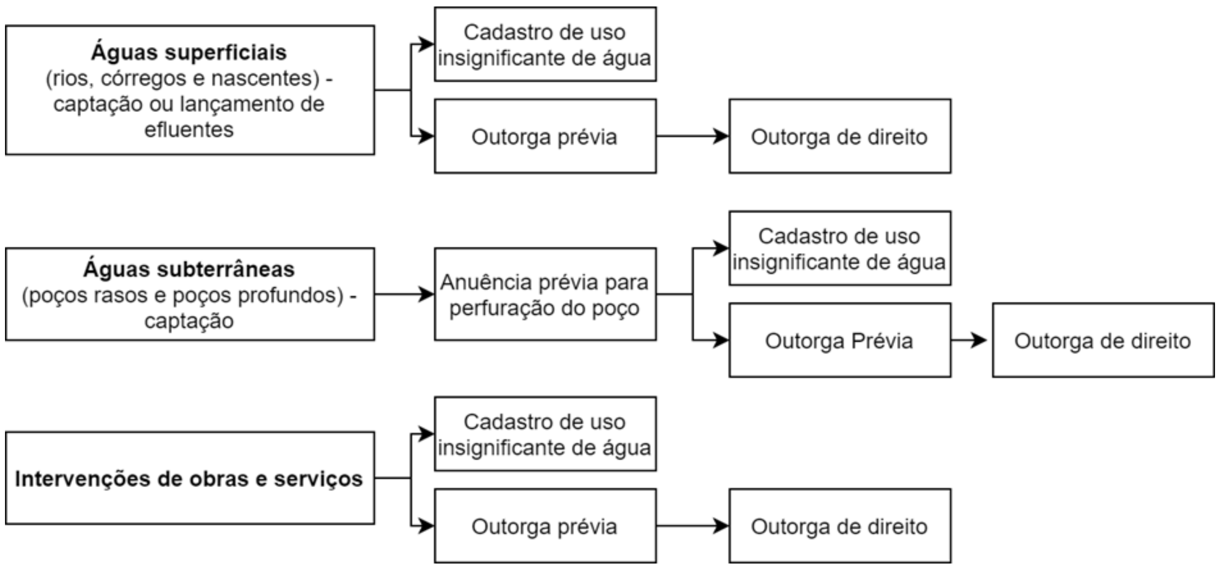

Figure 4-2 Authorizations by type of source and use of water resource. Source: IAT, 2023.

According to Decree 9.957/2014, uses that do not require a grant are commonly referred to as insignificant uses and must be registered as insignificant water uses. Following the definition in Ordinance 130/2020 of the Water and Land Institute, the following accumulations, derivations, abstractions and releases are exempt from granting, and are considered insignificant uses:

- Accumulations and dams on watercourses with a volume of up to 15,000 m^3, and with a water mirror area of less than or equal to 10,000 m^2, and with a dam height of less than 1.5 m;
- Diversions and individual catchments of up to 5.4 m^3/h or 129.6 m^3/day in aquaculture activities;
- Diversions and individual catchments of up to 1.8 m^3/h for other activities (except aquaculture);
- Effluent discharges into bodies of water with a flow rate of up to 1.8 m^3/h.
- Catchments intended for family consumption by landowners and population groups of less than or equal to 400 (four hundred) inhabitants dispersed in rural areas.

For new ventures that require environmental licensing and existing ventures that do not yet have environmental licensing, a Prior Grant must first be applied for, followed by a Right Grant.

The permit requirement applies to anyone who wants to use surface water (river, stream, brook, lake, mine or spring) or groundwater (deep tube wells or shallow wells) for a wide variety of purposes, such as domestic supply, public supply, firefighting, human consumption, particulate emission control, animal watering, dilution of sanitary or industrial effluents, industrial processes and general use. Therefore, the Program structures that will require this procedure will be the farms (if they don't already have one), the biogas plants and the Syncrude plant.

It should be noted that all surface and groundwater abstractions, including cacimba (shallow) wells, bridge wells, among others, must follow the stages of prior consent and grant or registration of insignificant use of water.

Effluent discharge permits are required for the purpose of diluting effluents from, for example, industrial production processes, sanitary systems (domestic and animal sewage), among others, as will be the case with biogas plants and the syncrude plant. Therefore, the discharge of effluents into natural watercourses may also require obtaining an Effluent Release Permit, also issued by the IAT in the case of the state of Paraná.

4.4.6 Additional records

Even though they are not directly inherent to environmental licensing procedures, it is common for licensing bodies to request additional proof in order to analyze and decide on the license. In this respect, for any undertaking that is seeking environmental compliance, there will be a need to comply with various parallel registrations and formalizations.

Some registrations can be mentioned in instances related to environmental regularity, but not directly inherent to environmental licensing, such as the property's Rural Environmental Registry (CAR), a self-declaratory instrument that determines regularity under the Brazilian Forest Code. There is also the self-declaratory registration with IBAMA for enterprises, and the Environmental Declaratory Act - ADA corresponds to the registration with the federal management body of rural properties that contain areas of environmental interest. The ADA is primarily intended for rural landowners to establish exemptions from the Rural Land Tax, however, when the rural property develops economic activities based on specific enterprises, the ADA is required by some environmental management bodies.

The same happens with the Federal Technical Register of Environmental Defense Activities and Instruments - CTF/AIDA, which corresponds to the mandatory technical responsibility register for the industry and commerce of equipment, apparatus and instruments designed to control activities that are effectively or potentially polluting.

Another example is the need to maintain a permanent technical manager for monitoring the environmental conditions of licensing, requiring a professional with active registration with the Professional Council and issuing the corresponding ART.

Although many of these registries and records are not directly linked to the licensing process, any active enterprise must comply with all the regularity requirements throughout the licensing and operational period. These complementary requirements usually require effort, time and financial resources to maintain, and will certainly have a significant impact on projects over time. Developments that are intended to serve regulated markets, such as the export market, are constantly required to comply with registrations and records in multiple territorial or socio-environmental management instances.

4.4.7 Variables relevant to licensing procedures

Considering that the basis of licensing is directly related to the potential impact that certain projects can have on the environment and society, which can be positive or negative, the main variable that influences licensing decisions is the location of the source that generates impacts and the area where these impacts can potentially radiate. Therefore, clarifying the exact location of projects in the territory and their areas of influence is a fundamental variable for licensing analysis.

The second influential variable in licensing analyses is the project's impact potential in terms of volume, intensity, duration and scale, among other aspects. In this sense, the regulations define this variable as the enterprise's "polluting potential" or "impact potential" (more appropriate, given that the enterprise being analyzed usually produces positive impacts and impacts not necessarily related to pollution).

These variables are explored in more detail below.

4.4.7.1 Area of influence of projects as an analysis variable in environmental licensing

The areas of influence of a project are defined as the space likely to undergo changes as a result of the implementation, maintenance and operation throughout the project's useful life. Therefore, the delimitation of the areas of influence of a project is determined by the territorial scope of the probable impacts foreseen in the environmental studies established according to consistent technical analysis, whether positive or negative, considering the physical, biological and anthropic environments.

Legally, the definition of areas of influence is based on CONAMA Resolution No. 01/86, which establishes the following guideline in Article 5, paragraph III:

- *III - define the limits of the geographical area to be directly or indirectly affected by the impacts, called the project's area of influence, considering, in all cases, the river basin in which it is located.*

The importance of previously defining the areas of influence at the start of environmental feasibility studies is directly related to the direction and preparation of the environmental diagnosis. In addition, defining the areas of influence helps in proposing mitigating and compensating measures and environmental programs aimed at recovering negatively altered areas or enhancing the impacts considered positive.

The areas of influence are usually delimited into three areas: Directly Affected Area (ADA), Area of Direct Influence (AID) and Area of Indirect Influence (AII). In addition, the definition of the polygonal boundaries of these areas is subject to studies of the physical, biotic and anthropic environments, and there may be differences in the scope of the definition of these areas of influence when environmental studies and subsequent analyses are carried out.

- Directly Affected Area (ADA): refers to the territorial area corresponding to the geographical perimeter to be effectively occupied by the project, including those intended for the installation of the infrastructure necessary for its implementation and operation, annexed areas such as parking lots, accesses, domain strips for pipelines and power lines, fences, various structures.
- Area of Direct Influence (AID): corresponds to the contiguous and extended territorial space of the ADA and is delimited by the territory where social, economic, cultural and environmental conditions may be primarily impacted, i.e. where there is a direct relationship of cause (implementation, operation and decommissioning of a given project) and effect (impacts).
- Area of Indirect Influence (AII): corresponds to the territory where the impacts are felt in a secondary or indirect way and, generally, to a lesser extent than the AID. For example, impacts of the project on the local or regional economy, indirectly affecting development processes.

It is worth noting that the areas of influence of a development are complex and encompass several interacting environments. The possible changes are varied, affecting air, water, soil, flora, fauna and human life in different ways, with different susceptibilities to atmospheric pollutants, water pollution, soil changes, ecosystem and species composition, income generation and improved quality of life. Therefore, these definitions must be made through an in-depth analysis of the different projects for the project, including the location of the farms, detailed piping layouts and the areas where the biogas plant and syncrude plant will be located.

4.4.7.2 Potential impact or polluting potential

The potential impact or polluting potential of an undertaking refers to the capacity or likelihood of a business activity, whether it be industrial production, agricultural production or even services, to have an impact on the environment. Normally, the qualification of an undertaking for licensing purposes is based on the potential for negative impact and/or the polluting potential that this particular undertaking may represent for the environment and society. This potential is assessed on the basis of the quantity, nature and toxicity of the waste, pollutants or impacts that may be generated during the construction, operation or decommissioning phases of an installation.

This assessment takes several factors into account:

- Type of Activity - certain industries or processes have a greater potential to generate pollution, such as those that deal with chemical substances, energy production, waste treatment, among others.
- Quantity and Nature of Waste - the quantity of waste generated, as well as its toxicity, biodegradability and persistence in the environment are assessed to determine the polluting potential.
- Technologies used - the type of technology used to control or mitigate environmental impacts is also considered. More advanced effluent treatment technologies, for example, can reduce the polluting potential of a project.
- Location and Environmental Vulnerability - the sensitivity of the environment around the facility also influences the potential for pollution. Areas close to fragile ecosystems, aquifers or natural habitats may be more susceptible to impacts.

The assessment of polluting potential is crucial in the environmental licensing process, as it allows regulatory bodies to determine which control, mitigation and prevention measures should be implemented to ensure that the project operates within acceptable environmental impact limits.

4.5 Licensing arrangements applicable to the Green Fuels Paraná Program

This chapter presents the arrangements and requirements applicable to environmental licensing for the various projects that are part of the Green Fuels Paraná Program.

As a reference for the analysis, in addition to researching data and information obtained from the developer, we also considered the structures and systems already installed at the Vila Ipiranga Pilot Plant, built by Me-Le in 2019, in terms of biogas/biomethane production.

As described in Chapter 2, the enterprises that make up the Program have been grouped into two Modules: the Primary Production Module, involving livestock farms and biogas production units, and the Syncrude Production Module.

Although the production units are integrated and interdependent, for the purposes of licensing, monitoring and control, it is essential to establish not only the instances of production, but especially the instances of legal responsibility for the various undertakings before the licensing bodies, since the licensing processes are established with registration in the name of the entrepreneur.

As such, arrangements were established for the developments and projections of the licensing instruments applicable to each of the developments considered.

It should be noted that, according to Article 6 of CEMA Resolution 107/2020, the framework and environmental licensing procedure to be adopted are defined by the relationship between the location of the activity or enterprise, its size and polluting/degrading potential, taking into account its typology.

For the licensing procedure, according to Article 8 of the aforementioned Resolution, it will be up to the competent environmental body to define the criteria for enforceability, detailing the list of undertakings, activities and works subject to environmental licensing and/or authorization, taking into account the specificities, environmental risks, size and other characteristics of the undertaking, activity or work.

According to Art. 56 of the same Resolution, the environmental studies will be defined according to the classification of undertakings and activities established in accordance with the matrix combining the polluting/degrading potential of the size. The Terms of Reference for the environmental studies to be required of the entrepreneur must be defined by the competent environmental body. In addition, specific studies may also be required for undertakings and activities located in areas of importance from an environmental point of view or which include innovative process technologies.

Also noteworthy is Article 80, the first paragraph of which establishes that the competent environmental body, having verified that the activity or undertaking does not potentially cause significant degradation and/or modification of the environment, will define the Environmental Studies pertinent to the respective licensing process. The second paragraph states that the environmental body may require, at any time, the presentation of a Risk Analysis in the case of the implementation of potentially dangerous technologies, especially when there is production, commercialization and use of techniques, methods and substances that pose a risk to life, quality of life and the environment.

Considering the above aspects, it is proposed that the licensing processes be carried out according to the arrangement illustrated in 4.3.

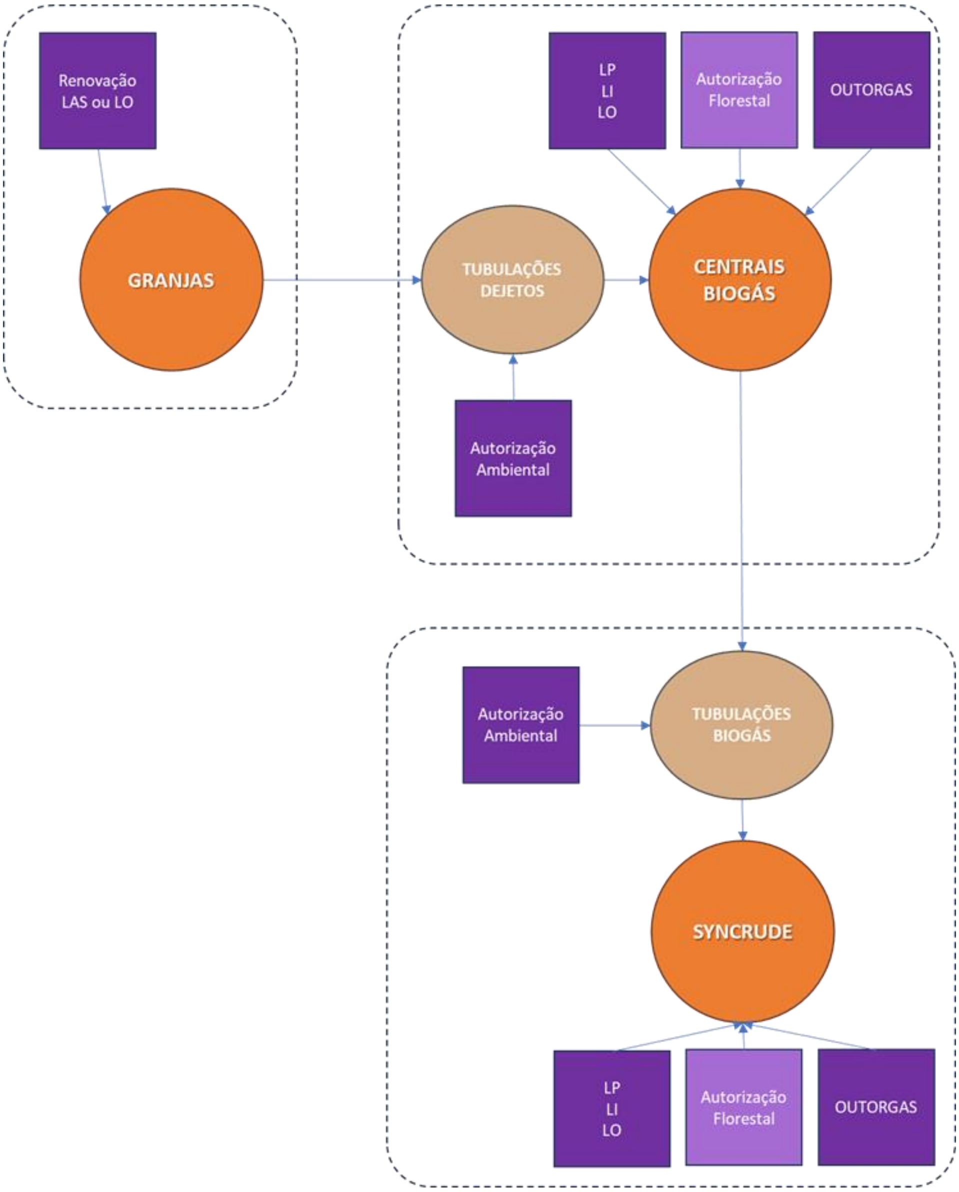

Figure 4-3 Demonstration of the licensing arrangements for the Green Fuels Paraná Program. Source: Author's elaboration, 2023.

Considering the above arrangement, the licensing processes should be organized as follows, in terms of legal responsibility:

- Farms - the legal responsibility for farms lies with the cattle rancher who owns them, so environmental licensing should be the responsibility of the farm owner, autonomously. Considering that new farms may be added to or excluded from the system, the autonomous licensing arrangement reduces the risk of the need for changes to the licenses of other enterprises. Environmental Authorizations or Simplified Environmental Licensing are applicable to the licensing and environmental regularization of farms, depending on the size of the farms.
- Biogas, Biomethane and Composting Plants - In the case of licensing Biogas Plants, the legal responsibility will fall on the entrepreneur/investor, or more likely, on the legal representative of the Cooperative that will

own the enterprise. According to records, the plants will be established under the legal form of an investment cooperative or rural production cooperative, owned by the cooperative members of the system. The licensing of this arrangement is mixed, and some activities may have simplified licensing in the form of Environmental Authorizations or Simplified Environmental Licensing, as is the case with pipelines and plant suppression authorizations (when applicable depending on the location of the plants). For biogas/biomethane production and composting units, depending on the volume of waste involved in the operation, environmental licensing must be full, taking into account the Preliminary Environmental License, the Implementation License and the Operating License. Surface and underground water use licenses are required (applicable to the artesian wells that the project must contain).

- Syncrude Plants - In the case of licensing the Syncrude Plant, legal responsibility will fall on the entrepreneur/investor who owns the project. The licensing of this arrangement is also mixed, and some activities may have simplified licensing in the form of Environmental Authorizations or Simplified Environmental Licensing, as is the case with pipelines and plant suppression authorizations (when applicable depending on the location of the plants). For biogas/biomethane production and composting units, depending on the volume of waste involved in the operation, environmental licensing must be full, taking into account the Preliminary Environmental License, the Implementation License and the Operating License. Surface and underground water use licenses are required (applicable to the artesian wells that the project must contain).

4.5.1 Potential socio-environmental impacts linked to the Green Fuels Paraná Program

The identification of potentially occurring environmental impacts must take into account all the different activities foreseen in the basic and executive projects. However, it is understood that the current stage of the project does not make it possible to indicate details about the operation of the project, for example, with regard to volumes of waste and effluents, or even the movement of loads and the circulation of vehicles that this movement will cause. Therefore, the analyses in this subchapter tend to be less complex due to the vagueness of certain items related to the operation of the project.

We started by assessing the resulting impact on components of the physical, biotic and anthropic environments, generically in the possible areas of influence of the project. The components in question are the elements likely to be affected by the planning, implementation and operation of the project. The resulting impact is understood to be the final residual effect (positive or negative) on each affected component, after all the impacting actions have been carried out and all the proposed preventive, mitigating and/or compensatory measures have been adopted.

During the planning phase, the actions of drawing up projects, negotiating areas, land and plots, appraisals, measurements and surveys tend mainly to produce changes in the real estate market and generate expectations and uncertainties. Eventually, changes can occur in the soil due to the movement of equipment and people.

In the implementation phase, the specific impacts are greater, generating changes in the soil, generation of particulates, reduction of vegetation cover, disturbance of fauna, changes in the landscape, among others. The implementation phase can also increase noise pressure in some areas, the risk of accidents at work or pollution, and changes in the real estate and services markets. These impacts generally result from activities such as earthworks, construction sites, crane and heavy machinery operations, hiring labor and building construction, among others.

During the operation of the project, impacts such as income generation and improved quality of life are expected, as well as changes in pressure on soil quality and water resources. In some places, there may also be changes in sound and atmospheric quality, as well as in the markets for energy, materials and services, income generation and the risk of accidents and environmental pollution.

Under the licensing arrangements identified, the farms will have a reduction in impacts, which could be significant, in their current areas of influence. The final disposal of waste in pastures, watercourses and other areas currently impacted by the establishments will be eliminated. It can therefore be seen that the environmental and social impact linked to the implementation of the project on the farms will be minimized compared to the current situation.

To facilitate a gradual understanding of all the elements involved in this process, they are presented below in the Table 4-3, Table 4-4 e Table 4-5 the actions and activities planned for each of the project's modules, their relationship with the potential impacts and an indication of the phase in which they may occur.

Table 4-3 Analysis of the potential impacts of livestock farms, organized and grouped according to the actions and activities planned for the planning, implementation and operation stages

GRENADES					
ACTIONS/ACTIVITIES	POTENTIAL IMPACTS	APPLICABILITY	PHASE		
			Planning	Implementation	Operation
Appraisals, measurements and surveys	Changes to the ground due to the movement of equipment and people		n		
Official implementation of the project	Changes in the real estate market, generating expectations and uncertainties		n		
Preparing accesses to farm areas	Changes in the soil, generation of particulates, particle transport	NA	-	-	-
Vegetation suppression in implementation areas	Reduction of vegetation cover, impacts on fauna, loss of habitats and disturbance of fauna	NA	-	-	-
Soil movement, earthworks and containment	Landscape change.	NA	-	-	-
Soil movement, earthworks and containment	Changes to the soil, generation of particulates, siltation of watercourses			n	
Soil movement, earthworks and containment	Changes in air quality and sound pressure.			n	
Soil movement, earthworks and containment	Risk of altering archaeological or historical/cultural sites, altering speleological heritage.	NA	-	-	-
Noise and vibration emissions	Interference with the behavior of some species of fauna				
Construction site assembly, operation and dismantling	Changes in sound quality, generation of sanitary waste, generation of solid waste, risks of accidents			n	

GRENADES						
ACTIONS/ACTIVITIES	POTENTIAL IMPACTS	APPLICABILITY	PHASE		
			Planning	Implementation	Operation
Fueling vehicles and machinery	Risk of accidents and oil and flammable spills	NA	-	-	-
Crane and heavy machinery operations	Changes in sound quality, risks of accidents, changes in the soil, generation of smoke and gases	NA	-	-	-
Hiring labor	Changes in the local and regional market related to employment and income			n	
Hiring labor	Hunting Activities			n	
Building construction	Changes in sound quality, risks of accidents, changes in the soil, changes in the services market			n	
Waterproofing areas	Soil sealing, concentration of rainwater flows			n	n
Movement of heavy vehicles	Changes in sound quality, smoke and gas production, accident risks, changes in regional traffic intensity	NA	-	-	-
Water consumption	Change in the supply market, impacts on effluent production				n
Electricity consumption	Change in the energy market, change in the supply network				n
Special solid, liquid and gaseous cargo handling	Changes in traffic intensity, risk of accidents with special loads				n
Solid waste production	Impacts on the recycling market and the market for the supply of specialized services				n
Production of liquid effluents	Impacts on the market for specialized services, risk of accidents with dangerous cargo, changes in the water regime				n
Production of gaseous emissions	Changes in air quality				n
Hiring specialized labor	Change in the regional employment and income market, change in the real estate market	NA	-	-	-
Animal production	Changes in municipal revenue, changes in the market for the supply of inputs and services	NA	-	-	-
Administrative production	Changes in the local and regional market for permanent and consumable services and materials, changes in local and regional trade	NA	-	-	-

GRENADES					
ACTIONS/ACTIVITIES	POTENTIAL IMPACTS	APPLICABILITY	PHASE		
			Planning	Implementation	Operation
Tax collection	Changes in municipal and state revenue, changes in the market for the supply of inputs and services	NA	-	-	-
Running over and killing wild animals	Risks of traffic accidents	NA	-	-	-
Power plant operation	Risks of electric shock accidents	NA	-	-	-
Maintenance of the company's equipment	Solid waste generation - electrical and electronic materials	NA	-	-	-

Legend: NA - Not Applicable. Source: Author's elaboration, 2023.

Table 4-4 Analysis of the potential impacts of the establishment of the Biogas Plants and Manure Pipelines project, organized and grouped according to the actions and activities planned for the planning, implementation and operation stages.

MANURE PIPES AND BIOGAS PLANTS					
ACTIONS/ACTIVITIES	POTENTIAL IMPACTS	APPLICABILITY	PHASE		
			Planning	Implementation	Operation
Appraisals, measurements and surveys	Changes in the soil due to the movement of equipment and people		n		
Official implementation of the Biogas Plant and Manure Pipes project	Changes in the real estate market, generating expectations and uncertainties		n		
Preparing accesses to pipe areas and biogas plants	Changes in the soil, generation of particulates, particle transport		n	n	
Vegetation suppression in implementation areas	Reduction of vegetation cover, impacts on fauna, loss of habitats and disturbance of fauna		n	n	
Soil handling, earthworks and containment	Landscape change.			n	n
Soil handling, earthworks and containment	Changes to the soil, generation of particulates, siltation of watercourses			n	

MANURE PIPES AND BIOGAS PLANTS					
ACTIONS/ACTIVITIES	POTENTIAL IMPACTS	APPLICABILITY	PHASE		
			Planning	Implementation	Operation
Soil handling, earthworks and containment	Changes in air quality and sound pressure.			n	
Soil handling, earthworks and containment	Risk of altering archaeological or historical/cultural sites, altering speleological heritage.			n	
Noise and vibration emissions	Interference with the behavior of some species of fauna			n	n
Construction site assembly, operation and dismantling	Changes in sound quality, generation of sanitary waste, generation of solid waste, risks of accidents			n	
Fueling vehicles and machinery	Risk of accidents and oil and flammable spills			n	
Crane and heavy machinery operations	Changes in sound quality, risks of accidents, changes in the soil, generation of smoke and gases			n	
Hiring labor	Changes in the local and regional market related to employment and income			n	
Hiring labor	Hunting Activities			n	
Building construction	Changes in sound quality, risks of accidents, changes in the soil, changes in the services market			n	
Waterproofing areas	Soil sealing, concentration of rainwater flows			n	n
Movement of heavy vehicles	Changes in sound quality, smoke and gas production, accident risks, changes in regional traffic intensity			n	n
Water consumption	Alterations to supply sources, impacts related to effluent production			n	n
Electricity consumption	Change in the energy market, change in the supply network			n	n
Special solid, liquid and gaseous cargo handling	Changes in traffic intensity, risk of accidents with special loads			n	n
Solid waste production	Impacts on the recycling market and the market for the supply of specialized services			n	n
Production of liquid effluents	Impacts on the market for specialized services, risk of accidents with dangerous cargo, changes in the water regime			n	n

MANURE PIPES AND BIOGAS PLANTS					
ACTIONS/ACTIVITIES	POTENTIAL IMPACTS	APPLICABILITY	PHASE		
			Planning	Implementation	Operation
Production of gaseous emissions	Changes in air quality			n	n
Hiring specialized labor	Change in the regional employment and income market, change in the real estate market				n
Biogas and electricity production	Changes in municipal revenue, changes in the market for the supply of inputs and services				n
Waste treatment and disposal	Changes in soil quality and water resources				n
Administrative production	Changes in the local and regional market for permanent and consumable services and materials, changes in local and regional trade				n
Tax collection	Changes in municipal and state revenue, changes in the market for the supply of inputs and services				n
Running over and killing wild animals	Risks of traffic accidents				n

Legend: NA - Not Applicable. Source: Author's elaboration, 2023.

Table 4-5 Analysis of the potential impacts of establishing the Syncrude and Biogas Pipeline Unit, organized and grouped according to the actions and activities planned for the planning, implementation and operation stages.

BIOGAS PIPES AND SYNCRUDE PLANT					
ACTIONS/ACTIVITIES	POTENTIAL IMPACTS	APPLICABILITY	PHASE		
			Planning	Implementation	Operation
Appraisals, measurements and surveys	Changes in the soil due to the movement of equipment and people		n		
Official implementation of the Syncrude and Pipeline Unit project	Changes in the real estate market, generating expectations and uncertainties		n		
Preparing accesses to the gas pipeline and syncrude unit areas	Changes in the soil, generation of particulates, particle transport		n	n	

BIOGAS PIPES AND SYNCRUDE PLANT					
Vegetation suppression in implementation areas	Reduction of vegetation cover, impacts on fauna, loss of habitats and disturbance of fauna		n	n	
Soil movement, earthworks and containment	Landscape change.			n	n
Soil movement, earthworks and containment	Changes to the soil, generation of particulates, siltation of watercourses			n	
Soil handling, earthworks and containment	Changes in air quality and sound pressure.			n	
Soil handling, earthworks and containment	Risk of altering archaeological or historical/cultural sites, altering speleological heritage.			n	
Noise and vibration emissions	Interference with the behavior of some species of fauna			n	n
Construction site assembly, operation and dismantling	Changes in sound quality, generation of sanitary waste, generation of solid waste, risks of accidents			n	
Fueling vehicles and machinery	Risk of accidents and oil and flammable spills			n	
Crane and heavy machinery operations	Changes in sound quality, risks of accidents, changes in the soil, generation of smoke and gases			n	
Hiring labor	Changes in the local and regional market related to employment and income			n	
Hiring labor	Hunting Activities			n	
Building construction	Changes in sound quality, risks of accidents, changes in the soil, changes in the services market			n	
Waterproofing areas	Soil sealing, concentration of rainwater flows			n	n
Movement of heavy vehicles	Changes in sound quality, smoke and gas production, accident risks, changes in regional traffic intensity			n	n
Water consumption	Alterations to supply sources, impacts related to the production of effluents			n	n
Electricity consumption	Change in the energy market, change in the supply network			n	n
Special solid, liquid and gaseous cargo handling	Changes in traffic intensity, risk of accidents with special loads			n	n
Solid waste production	Impacts on the recycling market and the market for the supply of specialized services			n	n
Production of liquid effluents	Impacts on the market for specialized services, risk of accidents with dangerous cargo, changes in the water regime			n	n

BIOGAS PIPES AND SYNCRUDE PLANT					
Production of gaseous emissions	Changes in air quality			n	n
Hiring specialized labor	Change in the regional employment and income market, change in the real estate market				n
Industrial production of syncrude	Changes in municipal revenue, changes in the market for the supply of inputs and services				n
Biogas treatment and disposal	Changes in the quality of air, soil and water resources				n
Administrative production	Changes in the local and regional market for permanent and consumable services and materials, changes in local and regional trade				n
Tax collection	Changes in municipal and state revenue, changes in the market for the supply of inputs and services				n
Running over and killing wild animals	Risks of traffic accidents				n

Legend: NA - Not Applicable. Source: Author's elaboration, 2023.

4.5.2 Environmental Licensing of Farms

There is no formal projection of the minimum or maximum number of farms that will be part of each biogas, biomethane and compost production module, but it can be assumed that there will be dozens of pig, poultry, dairy and fish production units. Each of the farms must be regularized in terms of socio-environmental aspects, by means of an Environmental License issued by the state regulatory body Instituto Água e Terra - IAT and by the Town Hall of the municipality where the farm is located.

While the pipelines and biogas and Syncrude plants will require the issuance of new three-phase environmental licenses, the farms, in turn, will need to amend and renew their licenses, covering changes to the treatment and disposal of effluents and the implementation of infrastructure in the production areas. The infrastructure is considered small, especially considering the size of the other structures on the farms and the production areas themselves.

These modifications will probably not lead to any changes in the size or polluting potential of each of the farms, and there will be no need to change the environmental licensing instrument for the establishments. Therefore, the process of obtaining environmental compliance for the farms involved in the project will be carried out by renewing the legal instruments in force, with the submission of information about the infrastructures to be implemented on the farms by the entrepreneur.

According to information, the majority of farms in the western region of Paraná already have Environmental Authorizations or Simplified Environmental Licenses, which makes them in good standing with regard to current legislation.

Even so, the current farm production system is set up without collecting, disposing of and treating waste in an optimized way, especially pig and cattle farms, since they use pigsties or lagoons to dispose of waste. The exception is farms that already have integrated biogas production systems, in which case the waste goes through a purification system and is reused for composting. Even so, there is plenty of scope for optimizing internal processes that can result in improvements to the environmental quality of the property and the region.

In the analysis of the scenario envisaged as a result of the implementation of the Program, it is considered that there will be changes in the processes of generating and discharging waste, especially due to the implementation of the rural sanitation network and the consequent removal of waste from the property. These changes make it compulsory for farmers to register with the environmental agencies in order to report changes to the systems, facilities and treatment of waste and effluents on their farms. Therefore, in practice, due to the changes in parameters and polluting potential, in principle reducing the risks and impacts, the environmental licenses of farms will have to be renewed.

Environmental licensing will be required for farms/producers that do not yet have an environmental license, for farms that are planning to expand or for new poultry production ventures that will join the Program. In these cases, licensing will be by Environmental Authorization or Simplified Environmental Licensing (LAS), or even full Environmental Licensing (LP, LI, LO), depending on the size of the enterprise.

According to Article 88 of CEMA Resolution 107/2020, definitive extensions and alterations to undertakings or activities that hold LAS or LO require specific licensing for the extended or altered part, adopting the same licensing criteria, and the entrepreneur is responsible for notifying the competent environmental body of such alterations or extensions in advance.

Environmental licenses for farms will be renewed upon presentation of an environmental study to be submitted by the applicant, which may be a Preliminary Environmental Report (RAP) or another more complex study determined by the environmental agency.

The RAP is a crucial document in the environmental licensing process for activities that have a lower potential for environmental impact, according to Article 56, item V of CEMA Resolution 107/2020. The RAP must address different aspects of the environmental diagnosis, detailing information on the physical environment, such as the topography and geology of the region affected by the pipeline installations, as well as aspects of the flora, fauna and socio-economic characteristics of the areas influenced by the implementation works.

The identification of environmental interventions is part of the RAP, considering an analysis of the executive project for the installation of the pipelines, which should detail all the actions that will be carried out for the works, such as excavations, earthworks, trenching and installation of the systems. This will make it possible to outline the potential environmental impacts, allowing an assessment of the possible risks and damage to the local ecosystem.

Based on this assessment, the RAP should propose mitigating and/or compensatory measures involving the presentation of strategies to reduce the impacts identified or, when it is not possible to avoid them, the definition of actions that compensate for or minimize these adverse effects. For example, environmental restoration of affected areas, the use of less impacting technologies or even the development of socio-environmental programs in the region.

It should be noted that the preparation of the RAP requires the inclusion of professionals with technical responsibility. This involves the participation of specialists who are trained and qualified to validate the report, ensuring its technical quality and compliance with legal requirements. These professionals are responsible for ensuring that all the information is accurate and in line with the standards set by the environmental agencies.

The environmental licensing of farms is fundamental for the certification of biogas and Syncrude production, and it is essential for the Program to require its members to maintain their farms in compliance with current environmental legislation.

4.5.3 Environmental Licensing of Biogas Plants

As we have already seen, the biogas, biomethane and composting production module involves farms, sanitation pipelines and waste treatment and gas production units. It is reported that the Program will establish 50 biogas production Modules involving dozens of feeder farms connected by manure transport pipelines and auxiliary systems such as pumping stations, inspection/visit stations and the like. The plants will also contain structures designed to generate electricity (those equipped with power generators based on combustion/biogas engines).

Because they are more complex undertakings, involving industrial facilities, pipelines laid over large areas, the collection and treatment of large volumes of waste, power generation equipment, the use of large volumes of water and the logistics of transporting potentially contaminating material by road (waste and compost), Biogas Plants should be subject to Full Environmental Licensing.

4.5.3.1 Prior License for Biogas Plant Installations

As already described, CEMA Resolution 107/2020 establishes, in its Article 87, that environmental authorization is required for works, temporary or emergency activities that may have an impact on the environment. It follows that the structures that are planned to make up the biogas production module will require full environmental licensing when there is a projection of implementing the programme in a more intense and organized way as a full enterprise. In the pilot format, although the legislation does not allow it, the structures could be granted fractional environmental licensing, precisely because it is an initial testing phase. In the event that the Program is actually implemented (no longer as a pilot), this split licensing is not recommended, resulting in the application of full environmental licensing.

In order to obtain the Preliminary License, the environmental agencies will require the presentation of a complete projection of the elements that will make up the biogas production module, involving the identification, characterization and geographic/locational referencing of all the construction elements. With this, the studies must include the outlines and dimensions of the rural sanitation network that will be part of the Module being licensed, the characterization of the structures, equipment and geographical positioning of the plants and their parallel structures (power lines, access roads), all at a level of detail characterized as "basic design".

In order to obtain the Preliminary License for biogas plants, the entrepreneur will be required to submit information and studies detailing the proposed project and its operation.

Biogas plants can be characterized as projects that generate electricity from the energy released in the form of heat through the combustion of biogas. In this case, CONAMA Resolution 01/1986 defines that the requirement for an EIA/RIMA for this type of project is only for generation above 10MW. As there are no plans for plants above this capacity, they can be licensed with a RAP, or another similar study of equal complexity.

However, it should be noted that, at the discretion of the environmental agency, biogas plants and the network of pipelines for transporting waste may fall under the sole paragraph of Article 59 of CEMA Resolution 107/2020, which establishes the requirement for an EIA/RIMA if, due to the peculiarities of the project and the impacts assessed, it is substantiated that this is an activity that potentially causes significant environmental impact. In this case, paragraph 2 of Article 76 and Article 80 corroborate the need to submit an EIA/RIMA.

CONAMA Resolution 01/1986 establishes the requirement for an Environmental Impact Study and its respective Environmental Impact Report (RIMA) for projects, activities and works involving sewage collection trunks and outfalls. Therefore, by similarity, it can be inferred that for sewage pipes, the environmental licensing process can be carried out by submitting an EIA/RIMA, which will be publicized and public hearings will be held.

The Environmental Impact Assessment (EIA) is a complex and comprehensive document required in environmental licensing processes for large-scale projects or those with a potentially significant environmental impact. Even though the pipelines represent a relatively small structure to be installed on each farm, along the way the agglutination of pipelines aimed at forming a rural sanitation network is representative if we consider the volume and length of the network in a biogas/biomethane production module, representing a potentially large environmental impact and risk.

In the EIA, viable technological and locational alternatives for the project are analyzed, seeking to identify options that minimize environmental and social impacts. This includes not only considering different technologies or execution methods, but also evaluating various locations for implementing the project, prioritizing less environmentally sensitive areas.

Delimiting the areas of influence involves identifying and characterizing the regions that will be directly or indirectly affected by the project, covering physical, biotic and socio-economic aspects. As already described, this delimitation is essential for understanding the scope of the impacts and planning appropriate mitigating and compensatory actions.

The detailed environmental diagnosis is one of the pillars of the EIA, analyzing the physical environment, flora and fauna, as well as the socio-economic aspects of the areas of influence. This assessment should provide crucial information on the current state of the environment, helping to identify environmental interventions during the project's implementation phase.

The assessment of potential environmental impacts is based on an analysis of the planned interventions, considering the proposed scenarios and the affected areas. This detailed analysis makes it possible to identify the positive and negative environmental risks and impacts that the project could generate, from changes in air and soil quality to possible effects on biodiversity and the local socio-economy.

Based on this assessment, the EIA proposes enhancing measures for potential positive impacts and mitigating and/or compensatory measures for negative environmental impacts predicted as a result of the analysis. Conditioning or compensatory measures can range from actions to preserve sensitive ecosystems to environmental education programs for affected communities. The inclusion of professionals with technical responsibility is also crucial, ensuring that the information is accurate and that the proposals meet legal and environmental requirements.

The Environmental Impact Report (EIR) is a summarized and accessible document, derived from the EIA, prepared during the environmental licensing process. Its purpose is to present the main results, conclusions and proposals contained in the EIA in a clear and comprehensible way to the affected community and interested parties. The RIMA highlights the significant impacts of the project on the environment and the community, discussing possible mitigating and compensatory measures. It serves as an essential tool for promoting public participation and transparency in decisions on projects that can influence the environment.

Finally, holding a public hearing is an important stage in the licensing process for projects with significant potential environmental impact. The environmental agency may, at its discretion, request that more than one public hearing be held to present the program to the public. The purpose of the hearings is to promote the participation of society, allowing access to information and contributions or even criticism of the Program.

It is important to note, in accordance with paragraph 4 of Article 71 and Article 74 of CEMA Resolution 107/2020, that for both LAS and full licensing, when it is necessary to cut or suppress native vegetation, the license can only be issued accompanied by the respective Forestry Authorization. In this case, the Flora Characterization Report, in accordance with CONAMA Resolution 02/1994, must be submitted in the licensing process itself.

The Flora Characterization Report comprises a detailed and systematic assessment of the flora and vegetation that could potentially be affected by the installation of the sanitation pipelines and biogas plant facilities. The report should provide an accurate diagnosis of the area that will be affected, indicating plant diversity, forest structure, species distribution and general ecosystem conditions. This information is essential for the environmental agency to determine mitigating actions and mandatory forest replacement to compensate for the individuals that will be suppressed by the infrastructure works.

As far as professionals and technical responsibility are concerned, it is essential that the EIA/RIMA be drawn up by a multidisciplinary team independent of the developer, and for the Characterization of the Flora the technical responsibility of a professional in the field of natural sciences or forestry sciences. These professionals are responsible for conducting the surveys, analyzing the information collected and preparing reports that meet the requirements of the environmental agencies.

4.5.3.2 Installation License for Biogas Plants

Once the Preliminary License has been obtained, the next step will be to obtain the Installation License for the projects that make up the biogas/biomethane production module.

In order to apply for the Installation License, the entrepreneur must submit detailed plans for the facilities and infrastructure, covering aspects such as engineering, environmental control systems, waste management plans, among others. These executive projects must accurately reflect the characteristics planned for the project, as well as the mitigating and compensatory measures proposed to reduce the environmental impacts identified in the EIA/RIMA.

It is important to note that compliance with the conditions set out in the Preliminary License is essential for the Installation License to be granted. The entrepreneur must demonstrate that he is in compliance with the previously established requirements, as well as ensuring that the environmental control systems and mitigation measures are being duly implemented.

In this case, according to Article 82 of CEMA Resolution 107/2020, the competent environmental agency may require the submission of an Environmental Control Plan (PCA), detailing the environmental plans and programs to be carried out when implementing the project.

The PCA expands on the EIA/RIMA strategies, offering a detailed plan of actions, outlining how they will be carried out, the resources needed, the timetable and those responsible. In addition, it requires the presence of qualified specialists to supervise execution, monitor results and make adjustments, ensuring compliance with the proposed measures.

In addition, the PCA also requires the presence of professionals with technical responsibility. As with the EIA/RIMA, the participation of qualified specialists is essential to guarantee the effectiveness and suitability of the measures proposed in the plan. These professionals not only supervise the execution of the actions, but are also responsible for monitoring the results obtained, making adjustments if necessary and reporting back to the environmental agency responsible for licensing.

State Decree No. 6.848/2009 provides for monetary environmental compensation to be applied at the time of the project's Implementation License, in the amount of 0% to 0.5% of the project's CAPEX, varying according to the size and scale of the project and its degree of potential impact.

With the Implementation License issued, the developer will be able to build the works and installations until the systems are commissioned.

4.5.3.3 Operating License for Biogas Plants

In order to obtain the Operating License, the entrepreneur must prove that all the measures provided for in the approved projects have been adopted, as well as demonstrating that the environmental control and monitoring systems are working properly. This includes compliance with waste management plans, monitoring of atmospheric emissions and effluent treatment, among other aspects relevant to environmental preservation.

The granting of the LO may include specific conditions that must be complied with during the operation of the project. These conditions are guidelines and requirements imposed by the environmental authority to ensure the continuity of activities in a sustainable manner, minimizing environmental impacts. The sole paragraph of Art. 86 of CEMA Resolution 107/2020 states that when applying to renew the Operating License, it may be required to submit periodic reports on monitoring, control and/or environmental recovery work, duly signed by the technicians responsible.

4.5.4 Environmental Licensing of Syncrude Production Unit

The Syncrude Production Unit comprises the connecting pipes between the biogas plants and the Syncrude industrial production unit itself.

For the licensing of this Module, there are two points of analysis in terms of the regulations in force. With regard to biogas pipelines, the project's classification under the regulations is, by similarity, equivalent to the licensing of pipelines. With regard to the Syncrude production unit, there is no specific designation in the regulations for the project's classification; therefore, by similarity, the industrial licensing regulations for chemical production and/or the transformation industry were established in the analysis.

4.5.4.1 Preliminary license for the Syncrude Production Unit

The work to lay the biogas pipeline connecting the biogas plants and the Syncrude plant, as well as the Syncrude plant itself, will require an environmental authorization and licensing process to be carried out with the environmental agency.

Article 59 of CEMA Resolution 107/2020 establishes that oil pipelines, alcohol pipelines, gas pipelines and poly pipelines are undertakings, activities or works with a significant environmental impact and, therefore, require the presentation of an EIA/RIMA, with the appropriate public hearing.

The same technical-administrative procedures as for the licensing process for biogas plants are expected for the Syncrude plant, as described above. It is possible, depending on the criteria adopted by the licensing body, for the Syncrude plant to be included in the sole paragraph of Article 59, and an EIA/RIMA should be required in the environmental licensing process if, due to the peculiarities of the undertaking and the impacts assessed, the undertaking, activity or works are potentially causing significant environmental impact. In this case, a Public Hearing must be held.

The EIA and its respective RIMA, as already described, are the environmental studies of an activity or undertaking that uses environmental resources, effectively or potentially causing significant pollution or other forms of significant environmental degradation, to be carried out beforehand in order to analyze its environmental viability.

Item VII of Article 59 of CEMA Resolution 107/2020 also defines that, in the case of gas pipeline projects, a Risk Analysis must be carried out in addition to the EIA/RIMA. The Risk Analysis of projects involves discerning the possible origins of dangers associated with the proposed activity, from the specifics of the project to the chemical substances and industrial processes involved. This approach aims to anticipate adverse situations that may arise during the execution of the project, enabling the implementation of appropriate preventive and control measures.

This study requires a comprehensive analysis of the geological, hydrological, biological and socio-economic aspects of the area affected by the project, as well as a detailed assessment of the environmental and social effects resulting from the project's activities. This process includes identifying the ecosystems affected, checking the quality of the air, water and soil, as well as considering the impacts on human health and local communities.

In addition, provision must be made for the respective Forestry Authorization, which authorizes the cutting or suppression of native vegetation for the implementation of the works. The Forestry Authorization requires the preparation of a Flora Characterization Report, in accordance with CONAMA Resolution 02/1994, in the licensing process itself, as part of the EIA/RIMA.

4.5.4.2 Installation license for the Syncrude Production Unit

As already described, when applying for the Installation License, the entrepreneur must submit detailed projects covering engineering, environmental control and waste management aspects. These projects must faithfully reflect the characteristics planned for the project, incorporating measures to mitigate environmental impacts as identified in the EIA/RIMA. Furthermore, compliance with the conditions set out in the Preliminary License is vital to obtaining the Installation License, requiring the entrepreneur to demonstrate compliance with previous requirements and ensure the implementation of environmental control systems and mitigation measures.

In accordance with CEMA Resolution 107/2020, the application for the Installation License for the biogas pipelines and the syncrude unit may require the submission of a PCA, detailing environmental plans and programs to be implemented during the project's implementation phase. The PCA deepens the strategies of the EIA/RIMA, offering a detailed plan of actions, with specifications on execution, resources, timetable and responsibilities. Qualified and technically qualified professionals must prepare this study and supervise its execution, monitoring the results and ensuring compliance with the proposed measures.

State Decree No. 6.848/2009 provides for monetary environmental compensation to be applied at the time of the project's Implementation License, in the amount of 0% to 0.5% of the project's CAPEX, varying according to the size and scale of the project and its degree of potential impact.

The Implementation Licenses for the pipelines and the Syncrude plant could be established in parallel and not linked, allowing the entrepreneur to establish separate equipment installation works for each project once they have been issued. However, this option requires a risk assessment of the environmental agency's deliberation deadlines, and there could be a mismatch or even obstacles in the deliberation, resulting in risks for the entrepreneur.

With the Implementation License issued, the developer will be able to build the works and installations until the systems are commissioned.

4.5.4.3 Operating license for the Syncrude Production Unit

In order to obtain the Operating License (LO), the entrepreneur must prove that the approved projects have been fully implemented, guaranteeing the full operation of the environmental control systems. This involves strict compliance with waste management, emissions monitoring and effluent treatment plans, ensuring compliance with environmental preservation requirements. In addition, the granting of the LO may contain specific conditions that guide the sustainable operation of the enterprise, with a view to minimizing environmental impacts. Furthermore, according to the sole paragraph of Article 86 of CEMA Resolution 107/2020, the renewal of the LO may require periodic monitoring, control and environmental recovery reports, signed by the technicians responsible.

4.5.5 Grants for the use of water resources

In addition to the environmental licensing of the projects, there is a projected need to apply for a Water Resources Use Grant, both because of the planned use of surface or underground water for use on the farms and in the industrial units, and because of the possibility of discharging industrial effluents at the Syncrude production unit.

For farms, depending on their size, there may be no need to issue a Water Resources Use Grant, since the amount of water used for washing and supplying livestock is considered "insignificant use". However, even if the permit is not required, it should be noted that the water abstraction must be registered with the IAT, in compliance with current regulations. The registration process is simple and should be the responsibility of each farmer who joins the program.

In the case of the use of water resources in large bolumes, according to Article 12 of CEMA Resolution 107/2020, the processes for obtaining water resource concessions are normally instructed by hydrogeological studies that analyze the environmental capacity of the body of water to supply water, either through a surface or underground source, or to receive effluents from an industrial process.

In the case of a groundwater abstraction grant, in addition to the hydrogeological study, with information on the location of the well, the intended flow rate for the system, geological information on the aquifers, geological structures, hydraulic characteristics and water quality, among others, the executive project for the abstraction well must be submitted, with a view to authorization for drilling (prior consent). The well's executive project must be accompanied by an Annotation of Technical Responsibility (ART) issued by a qualified professional.

In the case of an effluent discharge grant, in addition to the hydrogeological study analyzing the flow and quality of the effluent, as well as the environmental viability of the receiving body, the Sewage Treatment Plant (STP) project must be submitted, accompanied by an ART issued by a qualified professional.

4.5.6 Environmental Compliance Matrix of the Green Fuels Paraná Program

A general matrix on the Program's regularity is shown below in Table 4-6. It mentions licensing guidelines, environmental requirements and the bodies involved in the different licensing arrangements for the project, covering farms, manure and biogas pipelines, biogas plants and the Syncrude plant.

The matrix outlines the specific processes for each arrangement, from the renewal of environmental licenses for farms to the procedures involved in licensing manure pipelines, biogas plants and syncrude plants, offering a comprehensive and structured overview of the steps and requirements for environmental licensing in different contexts.

Table 4-6 Guidance matrix for the project's environmental licensing process, considering the different viable arrangements for the process.

ARRANGEMENT		LICENSING INSTRUMENTS	ENVIRONMENTAL REQUIREMENTS	INSTANCES INVOLVED	REMARKS
1	GRENADES	Renewal of LAS or LO	• RAP	IAT Rural Producers	

ARRANGEMENT		LICENSING INSTRUMENTS	ENVIRONMENTAL REQUIREMENTS	INSTANCES INVOLVED	REMARKS
				Cooperatives	
2	WASTE DUCTS	Environmental Authorization	• EIA/RIMA • Flora Characterization Report • PCA	IAT	
	BIOGAS PLANTS	LP	• RAP • Flora Characterization Report	IAT IPHAN City Hall	
		LI	• PCA • Compliance with the LP	IAT IPHAN City Hall	Sequential instrument after LP
		LO	• Compliance with the LI	IAT IPHAN City Hall IBAMA Federal Police * Ministry of Defense *	Sequential instrument after LI
		Water allocation (surface)	• Application • Hydrogeological study	IAT ANA **	If necessary
		Water allocation (underground)	• Application • Hydrogeological study • Well Executive Project	IAT ANA **	If necessary
		Effluent licensing	• Application • Hydrogeological study • ETE project	IAT ANA **	
3	BIOGAS PIPES	Environmental Authorization	• EIA/RIMA • Characterization of the Flora • Risk Analysis • PCA	IAT	

ARRANGEMENT	LICENSING INSTRUMENTS	ENVIRONMENTAL REQUIREMENTS	INSTANCES INVOLVED	REMARKS
SYNCRUDE PLANT	LP	• EIA/RIMA • Risk Analysis • Flora Characterization Report	IAT IPHAN City Hall	
	LI	• PCA • Compliance with the LP	IAT IPHAN City Hall	Sequential instrument after LP
	LO	• Compliance with the LI	IAT IPHAN City Hall IBAMA Federal Police * Ministry of Defense *	Sequential instrument after LI
	Water allocation (surface)	• Application • Hydrogeological study	IAT ANA **	If necessary
	Water allocation (underground)	• Application • Hydrogeological study • Well Project	IAT ANA **	If necessary
	Effluent licensing	• Application • Hydrogeological study • ETE project	IAT ANA **	

* if restricted products are handled ** if federal water resources are used
Source: Author's elaboration, 2023.

4.6 Benchmark Assessments of Greenhouse Gas Emissions in the Green Fuels Paraná Program

In September 2023, the Federal Government extended Brazil's commitment to reducing greenhouse gas emissions from 37% to 48% by 2025 and by 2030, the forecast had risen from 50% to 53%. In view of these new Nationally Determined Contributions (NDCs) established by the Brazilian government, the efforts of all parties, governments, society and companies have gained strength and also greater responsibilities to work towards compliance with the NDCs.

Inter-federative relations between countries to combat climate change are ensured by the provisions of the Kyoto Protocol (1997), its Cap and Trade and CDM mechanisms, and the Paris Agreement (2015/2016). From these arise various opportunities for Brazil to act and develop programs to combat climate change or carbon programs in joint actions and public-private partnerships, including with international federations.

Every carbon program needs to establish its baseline. Whether this is to demonstrate the greenhouse gas emissions that the scope of the program will cover and deal with, or carbon stocks to determine avoided emissions or to determine the volumes of carbon that will be added to the baseline. Determining the baseline is fundamental to any program, and can be more or less complex, and consequently require more or less effort.

The Rural Sanitation, Bioenergy, Biofuels and H2V - Green Fuels Paraná Program is planned to be implemented in eighteen municipalities in the west of Paraná, with the city of Toledo as the main hub, and therefore has the potential to involve a wide range of social actors, such as the government, academia, private companies and rural producers.

The *Green Fuels* Paraná Program aims to present new technologies for the disposal and treatment of organic animal waste, with socio-environmental and economic additionalities for rural producers and the local, state and national economy. These new technologies have a high potential for reducing local and regional environmental pollution, as well as reducing the effects and socio-economic damage linked to the processing of this waste throughout its life cycle, from the cradle (generation) to the grave (final disposal on the farm).

In the current scenario, conventional waste management practices in these eighteen municipalities cause a lot of socio-environmental damage, such as the emission of methane, ammonium and hydrogen sulphide gases, with the production of odors and contaminating particulate matter; the production of liquid or semi-solid waste with high nitrogen and phosphorus loads; production of socio-economically important pests for the development of agricultural and urban activities, animal and human diseases, environmental stress in animal production areas and consequently an increase in animal mortality rates, a high rate of natural water consumption, management conflicts during periods of drought and water stress, and during periods of excessive rainfall which cause anaerobic lagoons to leak.

As a result, there are severe local environmental limitations to the expansion of livestock production in the region, including the blocking of new environmental licenses, even considering the large potential socio-economic horizon to be explored with the expansion of livestock farming. The solution, even if only partial, for the treatment and disposal of animal production waste represents an opportunity to expand livestock production on a sustainable basis.

The treatment of manure using other technologies will also generate additional environmental gains, since the laws regulating the application of manure in the field are becoming more restrictive with regard to the presence of phosphorus. And new technologies will even facilitate the implementation of Frimesa's production expansion plans, which aim to double its pig production.

Other problems can also be addressed by the Program, such as better management of water resources, improving and guaranteeing agricultural productivity, integrating and solving problems arising from the management of dead animal carcasses, improving the management of poultry litter, reducing animal mortality due to improved production environments, reducing the risk of contamination of soil and water resources, the human well-being of rural producers and the communities and societies around them, and the increase in income for the recovery of the capacity and economic empowerment of rural producers and their farming families.

The *Green Fuels* Paraná Program, in addition to its objective of transforming waste management techniques, has the potential to promote improvements in the well-being of rural producers, their properties and animal production processes. These benefits will be brought about by technological innovations and changes to the energy matrix of properties with the implementation of the Distributed Generation system and by the potential return of income to producers due to the increase in remuneration derived from the provision of effluents usable in the production of biogas and biomethane, since the system presupposes cooperative organization for the provision of production inputs at the plants.

In addition to the socio-environmental benefits listed above, this chapter presents reference calculations of the greenhouse gas (GHG) emissions avoided in the atmosphere as a result of the implementation of the *Green Fuels* Paraná Project. These projections provide a view of how representative the project will be, once implemented, in terms of its contribution to climate change adaptation measures, as well as providing a benchmark for entrepreneurs in terms of the potential related to the carbon market. And their contributions to the Brazilian NDCs.

The baselines for conventional (*business as usual*) waste treatment systems and other processes involved in the Program's production and value chains are set out here, presenting important considerations for boosting contributions to the fight against climate change and socio-environmental improvements in local agricultural production systems.

4.6.1 Methodological Approach

The baselines of a carbon program are fundamental, as they determine the milestones linked to processes and systems, as well as their opportunities for sequestration and fixation, reduction and possibilities for avoided emissions. All programs need to present their baselines in order to be validated on the carbon market and accepted in the processes for recognizing their benefits (certifications). Without baselines, no program has the technical or economic viability to comply with national or international NDCs.

Baselines must be defined using methodologies validated by the UNFCCC/IPCC and must be aligned with the program's objectives and goals. To this end, compliance with international validation and certification agreements is essential, starting with registration with one of the international CDM, VERRA or Gold Standard schemes. These certify methodological compliance through *due diligence* analysis, baseline validation, field audits and verification of the processes, values and results presented in the project documents.

A greenhouse gas (GHG) emission baseline must delimit the scope of the program's emissions, comply with the methodology validated in the UNFCCC, and present results in full accordance with the methodological assumptions. Likewise, the baselines for sequestering and fixing carbon in natural or anthropogenic systems, and maintaining carbon stocks, through the values of carbon that will not be emitted.

The Green Fuels Paraná program has a direct bias in the baselines of emissions avoided by technological change, such as changing the treatment of manure, changing the energy matrix, generating low-carbon energy source products that can replace high-carbon energy sources and an indirect bias in the use of biodigestate as a source of nutrients for agricultural production.

The materials used for this work were reports, data and information on the *Green Fuels* Paraná Program. Therefore, the analyses carried out were based on secondary data obtained directly from the entrepreneurs (Me-Le) and the other consultants involved in the H2UPP project, and also involved interviews with technicians linked to the Program.

We used data from the Sicredi Avoided Methane Umbrella Program, developed in Paraná and Santa Catarina and registered on the VERRA platform - 4925 https://registry.verra.org/app/projectDetail/VCS/4925, considering primary data on emissions from pig and cattle production.

The following methodologies were used to construct methane emission baselines from animal waste treatment lagoons:

- AMS-III.Y - Small-scale methodology - Methane avoidance through separation of solids from wastewater or manure treatment systems; e,
- AMS-III.I - Avoidance of methane production in wastewater treatment through replacement of anaerobic systems by aerobic systems (Version 08)

For the volume of waste produced annually per animal, data from the literature was used for fish and poultry, which was cross-referenced with data sources from AMAR SUSTAINABILIDADE for pig and cattle farming, using the AMS-III.Y methodology - *Small-scale methodology - Methane avoidance through separation of solids from wastewater or manure treatment systems*.

In accordance with the AMS.III-Y methodology (version 04), the emissions generated in the conventional system for treating animal waste in anaerobic lagoons were calculated using the following calculation methods, according to the equations below.

$$BEy = UFb \times (Qy_{,,} \times CODy, in - Qy, ww, out \times CODy\ 4/1000 \quad (\text{Equation 1})$$

Where:

UFb	=	Model correction factor to take into account model uncertainties (0.89)8
$Qy_{,,}$	=	Volume of wastewater entering the solids separation device in year y (m^3)
$CODy, in$	=	Chemical oxygen demand of the wastewater entering the solids separation device (kg/m^3)
$Qy_{,,}$	=	Volume of wastewater leaving the solids separation device in year y (m^3)
$CODy,$	=	Chemical oxygen demand of the wastewater leaving the solids separation device (kg/m^3)
$Bo,$	=	Methane production capacity of wastewater (IPCC default value of 0.25 kg CH_4 /kg COD or 0.6 kg CH4/kg BOD)
$MCFww,$	=	Methane correction factor for the baseline anaerobic wastewater treatment system

The reference emissions are calculated using Equation 1 of the AMS III.Y methodology (version 4), and Equation 2 is used to determine the net emissions of the conventional animal manure treatment system.

$$BE_y = BE_{ww\ treatment\ y} + BE_{ww\ high\ y} + BE_{s\ treatmenty} + BE\ s_{final\ y} \quad (\text{Equation 2})$$

Where:

BE y	=	Reference emissions in year y (tCO2e)
B ww treatment y	=	Treatment y Methane produced in the baseline anaerobic wastewater treatment system(s) being replaced by the aerobic biological system(s) (tCO2e)
BE ww high y	=	Methane emissions due to inefficiencies in basic wastewater treatment systems and the presence of degradable organic carbon in treated wastewater discharged into rivers/lakes/seas, etc. (tCO2e)
BE s treatment y	=	Methane treatment produced in the baseline sludge treatment system(s) (tCO2e)
BE s final	y=	Reference methane emissions from the anaerobic decomposition of the final sludge produced (tCO2e)

It should be emphasized that the *BE ww y* treatment is the only one applicable to this project. Therefore, it is the only one considered for the equation, which results in equation 3:

$BE_y = BE_{ww\ treatment\ y}$ *(Equation 3)*

Where,

BE y	=	Reference emissions in year y (tCO2e)
BE ww treatment y	=	Methane produced in the baseline anaerobic wastewater treatment system(s) that is/are being replaced by the aerobic biological system(s) (tCO2e)

These methodologies are registered with VERRA and the UNFCCC and the data on the static herd of cattle, pigs and poultry was provided by the management team of the Rural Sanitation Program, Bioenergy Biofuels and H2V *GREEN FUELS* PARANÁ Energy Transition + Circular Economy.

The methodological steps included the annual harmonization of all the data and subsequent normalization to the functional unit of m^3 of methane from the various sources, since in order to calculate and define the baseline it is necessary to consider the time frame of one year. For this reason, data was adjusted to technical production and management issues for one year.

In Table 4-7, as reported by the *Green Fuels* Paraná Program, shows the numbers of animals in the eighteen municipalities involved in the program's study area, the amount of manure generated per animal and per herd.

Table 4-7 Number of animals in the annual herd of the eighteen municipalities in the program, the relative and absolute quantities of waste generated in a year.

ANIMALS	PLANT	DEJECT PER ANIMAL (kg/year)	LIVESTOCK MANURE (kg/year)
Fish	125.000.000,00	8,93	1.116.250.000,00
Birds	73.649.650,67	8,00	589.197.205,33
Pigs Finishing	3.149.193,00	4.175,60	13.149.770.290,80
Sow Pigs (UPL)	239.048,00	10.249,20	2.450.050.761,60
Piglets Piglets (nurseries)	3.742.758,00	1.138,80	4.262.252.810,40
Cattle	30.000,00	17.082,00	512.460.000,00
TOTAL	-	-	22.079.981.068,13

Source: AMAR Sustainability (2024), based on information from Me-Le GbmH (2024).

4.6.2 Emissions Analysis

The region's conventional (*business as usual) waste* treatment system is an anaerobic lagoon for semi-solid waste from pig and cattle farming; for fish farming waste, it is land application without chemical and biological control; for poultry farming waste, it is land application as a source of nitrogen, both poultry litter and waste from carcasses and eggs. These systems of open-air manure application, without chemical or biological control, are sources of high greenhouse gas emissions during the decomposition of organic matter.

An analysis of the figures in Table 1 shows the large volume of waste generated by each type of animal, as well as the total volume of the animal herd over the course of a year, corresponding to 22,079,981.07 t/year. Certainly, this large volume of material to be treated, dispersed or applied to agricultural land in the eighteen municipalities in the *Green Fuels* Paraná program study area represents significant impacts on the environment and society. So much so that there are environmental licensing limitations for the expansion of livestock farming in the region, indicating that the load of waste currently produced tends to reach or even exceed the maximum load capacity and nutritional purification capacity in natural and man-made environments, due to the ecotoxicity, acidification and eutrophication of local soils and waters, mainly due to the presence of phosphorus (P), an element with high polluting power in the environment.

The following baseline results were obtained from the *Green Fuels* Paraná Program considering the established production modules, namely agricultural production, biogas production, biomethane and Syncrude production.

4.6.2.1 Emissions Analysis in the Livestock Production Module

Based on the data presented in Table 1, the methane emission values for manure production were calculated using the AMS-III.Y methodology, considering each type of animal and based on the current herd in the study region, as informed by the entrepreneur. In Table 4-8 shows the emission values of the resulting baselines.

In order to verify the estimated manure production of the 18 municipalities mentioned, the research developed by Sordi, Alexandre et al. (2005) on the potential daily generation of biogas from poultry manure, which is 0.014 m^3 per bird, was used. Embrapa Swine and Poultry in Concordia-SC has developed a platform for calculating the potential for generating waste and biogas (Biogásforte, 2018), so the data obtained came from this platform for finishing pigs, sows (UPL) and piglets (nurseries), as well as data on direct GHG emissions from animal production.

Table 4-8 Ratio of manure per animal, volume of GHG emissions per manure and for the total herd of animals, in one year

ANIMALS	TOTAL ROSTER	EMISSIONS (kg/animal/year)	GHG EMISSIONS FROM THE PLANT PER YEAR (TCO_2 E/year)	GHG EMISSIONS FROM THE PLANT IN 10 YEARS (TCO_2 E/10 years)
Fish	125.000.000,00	0,73	1.358,10	13.581,04
Birds	73.649.650,67	0,32	885,84	8.858,42
Pigs Finishing	3.149.193,00	880,00	9.643.164,88	96.431.648,80
Sow Pigs (UPL)	239.048,00	2.000,00	4.083.417,94	40.834.179,36
Piglets Piglets (nurseries)	3.742.758,00	180,00	639.337,92	6.393.379,22
Cattle	30.000,00	21.070,00	8.997.943,50	89.979.435,00
TOTAL	-	-	23.366.108,18	233.661.081,83

Source: AMAR Sustainability (2024), based on information from Me-Le GbmH (2024).

Analyzing Table 4-8 it can be seen that manure, in the current system for its treatment, is a source of high emission rates of methane ($CH4$) or carbon dioxide equivalent ($CO2$ e), the main greenhouse gases (GHG). These gases, if released freely into the atmosphere, are precursors of climate change processes due to their large quantities, representing a high potential influence on global warming.

Also in Table 4-8 shows the potential volumes of GHG emissions (methane - CH_4) that could be reduced if another technology and waste treatment system were used instead of anaerobic lagoons (business as usual). In this case, the Green Fuels Paraná Program, if implemented on the scale and operational intensity planned, will have the potential to avoid the emission of 23,366,108.18 tCO_2 e/year, generating carbon credits that can be traded on international platforms and can be taken into account when accounting for national NDCs or can be used to neutralize production systems. The 100% elimination of anaerobic lagoons is unlikely, but the numerical calculations presented above give an indication of the current challenges facing the region due to the real emissions of the current scenario.

If the volumes of emissions avoided were extrapolated over a ten-year period, as proposed by the AMS-III.Y methodology, maintaining the current plantations, the total projected volume of emissions would be 233,661,081.83 tCO_2 over 10 years.

4.6.2.2 Analysis of the potential for Avoided Emissions in the production of Biogas And/Or Biomethane

The *Green Fuels* Paraná Program establishes the production of biogas and biomethane from the use of animal waste as a new technology for reducing emissions presented in the baseline replacement of the business as usual manure treatment system. This represents a direct reduction in emissions of methane and other gases into the atmosphere.

This new technology, in addition to changing the way animal waste and effluents are treated and disposed of, will, when in operation, result in the minimization of the negative socio-environmental impacts listed above, combined with positive contributions to combating climate change, as well as boosting other opportunities for economic gains that will certainly be reflected across the entire spectrum of Program participants.

Animal waste has the potential to generate biogas in local or group biodigesters. Table 4-9 shows the potential values for biogas generation from each type of waste generated by the animal herd over the course of a year.

Table 4-9 Potential volume of biogas generated from the volume of animal waste for one year's herd.

ANIMALS	DEJECT/PLANT/YEAR (kg/year)	BIOGAS GENERATION POTENTIAL (m^3/year)
Fish	1.116.250.000,00	NE
Birds	589.197.205,33	2.448,67
Pigs Finishing	13.149.770.290,80	3.830.840,06
Sow Pigs (UPL)	2.450.050.761,60	175.199,31
Piglets Piglets (nurseries)	4.262.252.810,40	259.198,37
Cattle	512.460.000,00	10.665,58
TOTAL	22.079.981.068,13	4.278.351,99

Source: AMAR Sustainability (2024) based on information from Me-Le GbmH (2024).

In Table 4.9 it can be seen that fish waste does not have the potential to generate biogas; however, it can be included in the treatment processes for animal waste on rural properties, since the vast majority of fish farmers carry out other agricultural activities.

It can be seen that the production of biogas (m^3) can contribute to the emission of a certain volume of tCO_2 and, depending on the type of waste considered, because each waste has its own chemical composition and specific characteristics, biogas from cattle waste has the highest rate of avoided methane emissions and poultry waste has the lowest rate of avoided methane emissions.

In the case of biogas from biodigesters, in addition to avoiding emissions from the natural degradation of organic matter in waste, there is also the possibility of converting methane (CH_4) into thermal and/or electrical energy sources, as well as the production of other products from biogas and biodigester waste, such as biodigestate.

If the volumes of emissions avoided were extrapolated over a ten-year period, as proposed by the AMS-III.Y methodology, maintaining current plantings, the total projected volume of emissions avoided would be 233,661,081.83 tCO2e/10 years.

4.6.2.3 Analysis of the potential for Avoided Emissions in Syncrude Production

Among the scenarios analyzed, 3 different scenarios were considered, of which A and B refer to the generation of Syncrude and aviation biofuel (SAF), with the difference in efficiency dealt with in scenario B due to the use of the water vapor change reaction; and for scenario C the exclusive production of Methanol is destined.

Scenario A - Syncrude and SAF + Recycles

Scenario B - Syncrude and SAF + Recycles + RWGS

Scenario C - Methanol

In Table 4-10 shows the potential uses of biogas for the production of Syncrude and methanol according to the technological descriptions presented in scenarios A, B and C of the Green Fuels Paraná Program.

Table 4-10 Potential use of biogas for the production of Syncrude and methanol.

ANIMALS	BIOGAS GENERATION POTENTIAL (m^3/year)	SYNCRUDE POTENTIAL (m^3/year) IN SCENARIO A	SYNCRUDE POTENTIAL (m^3/year) IN SCENARIO B	METHANOL POTENTIAL (m^3/year) SCENARIO C
Fish	NE	NE	NE	NE
Birds	2.448,67	609,11	861,20	1.244,28
Pigs Finishing	3.830.840,06	952.920,69	1.347.313,68	1.946.627,87
Sow Pigs (UPL)	175.199,31	43.580,79	61.617,93	89.026,91
Piglets Piglets (nurseries)	259.198,37	64.475,54	91.160,56	131.710,74
Cattle	10.665,58	2.653,06	3.751,10	5.419,68
TOTAL	4.278.351,99	1.064.239,19	1.504.704,47	2.174.029,48

Source: AMAR Sustainability (2024) based on information from Me-Le GbmH (2024).

4.6.2.4 Analysis of the Potential for Fugitive Emissions based on Electricity Consumption

In the case of the Green Fuels Paraná program, which will use biogas to produce methane, carbon dioxide (CO_2), biohydrogen, Syncrude (C_nH_{2n}) and other derivatives, large amounts of energy will be consumed in production processes. The consumption of this large amount of energy determines the so-called "generation of fugitive energies", which can have different GHG emission rates depending on their origins (energy sources).

The potential for minimizing, or even eliminating, the release of methane and other gases into the atmosphere from organic matter biodigestion technology, considering the possibilities for using biogas to build Syncrude and Methanol production scenarios, are presented in Table 4-11. This is based on a theoretical projection based on data provided by the developer, with analysis backed up by primary data obtained from the project developed with SICREDI, as already mentioned, and using emissions data for Electricity, from a hydroelectric energy source.

Table 4-11 Conversion/transformation ratio and generation of syncrude and methanol from biogas in scenarios A, B and C with hydroelectric energy matrix

Methanol and Syncrude Emissions Scenarios	Biogas conversion potential / Syncrude	Quantity of biogas for Syncrude production	Total emissions avoided	EE Hydroelectric Emissions tCO2e / t of Product	Net GHG emissions tCO2e/ton of product
Unit	t/t	t/t	tCO2e	tCO2e	tCO2e
Scenario A	0,249	4,0201	68,03	60,6526	7,38
Scenario B	0,352	2,8433	48,11	42,8980	5,22
Scenario C	0,508	1,9679	33,30	237,6166	- 204,32

Source: AMAR Sustainability (2024) based on information from Me-Le GbmH (2024).

Considering the use of hydroelectric power for the production of Syncrude and Methanol in scenarios A, B and C, their total production volumes and according to the Table 4-11. In scenario A, the net emission is 7.38 tCO2 and avoided per ton of final product; in scenario B the net emission is 5.22 tCO2 and avoided per ton of final product; and in scenario C the net emission is an additional -204.32 tCO2e per ton of final product. In other words, scenario C generates more GHG than it would avoid.

The deduction of fugitive emissions generated by the consumption of energy to carry out biogas production operations and their derived products, as well as their co-products, is mandatory according to the UNFCCC/IPCC/VERRA methodology and the Gold Standard. And these fugitive emissions can lead to negative final net balances.

As can be seen, the total annual volume of emissions avoided, considering the current herd indicated by the company, amounts to 23,366,108.18 tCO2 e/m^3 /year. It should be noted that the actual methane avoided in the technological generation process differs from that estimated from the methagenic potential of the manure in natura. This is due to the efficiency factor of the system and the technology used in technological scenarios A, B and C.

In Table 4-12 are examples of GHG emissions for each type of energy source that can be used in production processes, considering the Program's scenarios, and which need to be deducted from the final volumes of emissions avoided in the processes considered. The same table shows the GHG emission rates for the production of each source of electricity to be considered. The fugitive emissions values for each energy source were calculated using the GHG Protocol method, due to the lack of primary data.

Table 4-12 Electricity consumption in the Green Fuels Paraná Program scenarios, with fugitive emissions from the different electricity sources per ton produced.

		Emission of tCO2e per t of Syncrude

Syncrude Production Scenarios	EE consumption (MWh/t of Syncrude)	Hydroelectric	Wind	Solar
Scenario A	1,58	60,65	0,03	0,1
Scenario B	1,11	42,9	0,02	0,07
Scenario C	6,17	237,62	0,12	0,41

Source: AMAR Sustainability (2024) based on information from Me-Le GbmH (2024).

In Table 4.12 it can be seen that the production of Syncrude and Methanol from hydroelectric power generates larger and more significant volumes of fugitive GHG emissions than the production of Syncrude and Methanol from wind and solar photovoltaic electricity sources.

Considering the maximum annual potential generation of Syncrude and Methanol from the volumes of biogas that can be obtained from biodigesters for treating animal waste. Through the biogas generated, the estimates of GHG emissions generated for the production of Syncrude and Methanol in scenarios A, B and C are shown in Table 4-12 considering the total possible production volumes for Syncrude and Methanol.

In table, 4.13, in Scenarios A and B, electricity consumption of 212,750.00 MWh/year is required for the production of Syncrude and in Scenario C the electricity consumption required for the annual production of methanol is 1,702,640.00 MWh/year. It should be noted that the Syncrude generated in Scenario B, despite needing the same amount of electricity as the Syncrude in Scenario A, has the lowest GHG emissions. Among the energy matrices, wind is the EE source with the lowest GHG emissions in all scenarios.

Table 4-13 Electricity Consumption in the Scenarios of the Green Fuels Paraná Program, with Fugitive Emissions from the Different Electricity Sources for Annual Production.

Syncrude Production Scenarios	EE consumption for Syncrude's annual production (MWh/year)	Annual tCO2e emissions		
		Hydroelectric	Wind	Solar
Scenario A	212.750,00	12.903.287,50	6.382,50	21.275,00
Scenario B	212.750,00	9.126.975,00	4.255,00	14.892,50
Scenario C	1.702+640,00	404.581.316,80	204.316,80	698.082,40

Source: AMAR Sustainability (2024) based on information from Me-Le GbmH (2024).

In Table 4-14 the net emissions balances for Syncrude and Methanol produced in scenarios A, B and C with the different electricity sources are shown.

Table 4-14 Balance of Emissions from the Different Sources of Electricity for Annual Production.

Syncrude Production Scenarios	Emission balance of tCO2e/year		
	Hydroelectric	Wind	Solar
Scenario A	10.462.820,68	23.359.725,68	23.344.833,18
Scenario B	14.239.133,18	23.361.853,18	23.351.215,68
Scenario C	- 381.215.208,62	23.161.791,38	22.668.025.78

Source: AMAR Sustainability (2024).

In Table 4.14 the balances of net GHG emissions are presented, showing that for the Hydroelectric energy matrix, scenario C presented environmental unfeasibility, with emissions generated higher than emissions avoided, at 381,215,208.62 tCO2e per year. Scenario B showed the highest avoided emissions, with a reduction of 23,361,853.18 tCO2e per year when using wind power.

4.7 Conclusions on the viability and environmental regularity of the Green Fuels Paraná Program

The *Green Fuels* Paraná Program is at the idealization and technical and financial feasibility studies stage. The program involves multiple projects spread over a wide area (18 municipalities) in an integrated system.

The approach presented here establishes perceptions about the Program's suitability in environmental terms and conclusions about environmental viability understood from the formal approach of licensing, taking into account the information available on the general set of projects that make up the Program and their potential effects on the environment and the society that inhabits the region.

At this stage of idealization and feasibility analysis of the Program, there is no information on specific variables that are fundamental for assertive environmental analysis, such as which production alternative will be adopted by the entrepreneur - Syncrude/SAF or Methanol - for example, or on the exact location of the structures and infrastructures that make up the Program. The detailed analysis of environmental licensing depends on the precise definition of the object to be licensed and the exact locational information to determine the feasibility of obtaining the licenses for the project. There is no such thing as generic environmental licensing or licensing for an undetermined location.

The environmental analyses carried out on all the elements that make up the proposal are, in a way, limited to the general conception of the Program, and are also based on the analyses carried out in the study called "Technical and Economic Feasibility Study of Biogas and PtX Production Plants for Me-Le in Paraná", presented in a specific report produced by professionals linked to the Federal University of Paraná and NIRAS. The study compares methane, biogas, methanol and Syncrude/SAF production scenarios, establishing comparative technical and economic feasibility analyses.

In terms of environmental licensing, the evaluation of the studies mentioned above indicates that there are important differences and factors in the various scenarios for producing biogas, biomethane, Syncrude/SAF and methanol, but they do not alter the form or the procedure for obtaining environmental licensing for the Program. Whichever alternative is adopted from the options presented in the study, for the production volumes considered, it will require full three-phase environmental licensing and water resource use grants. This conclusion can be drawn from the framework of the projected size of the projects and the volume of production envisaged, with all the alternatives presented establishing a similar framework with regard to the regulations in force.

While on the one hand there will be no significant difference in the way licensing is obtained, there will certainly be significant differences in the environmental conditions applicable to the Program, depending on the alternative adopted. For example, the variable production projections for processes 1, 2 and 3, as presented, indicate a variation in the volumes to be produced from 7.5 to 22 tons/h. This variation already defines, albeit simplistically, a change in the size and volume of production that will have an impact on the licensing process and certainly on the number of environmental conditions to be met. However, it is important to note that these changes will not create major differences in the challenges of compliance, since the environmental conditions are expected to be similar between the alternatives adopted.

Care should be taken to consider Environmental Compensation in relation to the alternative adopted. It should be noted that Environmental Compensation is a different tool from Environmental Conditioning, the former being applied monetarily as a fraction of CAPEX ranging from 0% to 0.5%, at the discretion of the licensing environmental agency. In the case of a project with a high value to be invested, this Environmental Compensation could represent a significant financial impact for entrepreneurs, bearing in mind that it will add costs to the other elements to be paid as a result of Environmental Licensing and the regularity of the project.

4.7.1 Environmental viability of the Green Fuels Paraná Program

Discussing the environmental viability of the program necessarily leads to two important approaches, the first referring to the suitability of the proposal in socio-environmental terms and the second relating to formal technical viability defined as being subject to environmental licensing.

In environmental terms, the region in which the program is located is considered to be in a critical situation, largely due to the impacts caused by the production of poultry, especially pigs and cattle. No matter how technologically advanced the farms are, the environmental conditions they present have major negative impacts not only on the farmers but also on the region, and are felt in all the communities and towns in the region. Soil and water contamination from effluent discharge and organic waste disposal, air contamination from high methane loads and odors from decomposing organic waste, are just a few approaches that can be mentioned.

From the analyses carried out, it can be seen that there is a great opportunity for environmental improvement, based on a paradigm shift in the way regional farming activity is handled, which, if implemented, will certainly serve as a model for implementation in other parts of the country. Establishing rural sanitation infrastructure will certainly bring about a significant change in the environmental quality and well-being of the region's population.

Optimizing the systems for collecting and conditioning animal waste on the property will immediately minimize the load of soil contamination caused by the percolation of wastewater from pigsties and similar archaic structures, as well as minimizing the contamination of watercourses on the property. Watercourses that contribute to a wide network of tributaries, resulting in expanded contamination of the basins of the main rivers in the western region of the state of Paraná, so the effect of this improvement will have regional irradiation.

Increased environmental health due to optimized collection and packaging will also help to reduce air pollution by reducing atmospheric emissions of gases such as methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S), ammonia (NH_3), among others. Although the system will not eliminate these emissions, the way the waste is contained and the reduction in the time the waste remains on the property due to the implementation of the structures provided for in the Program will contribute to a significant reduction in these emissions. In addition, the impact of the odors emanating from these pens should also be reduced. More frequent washing of the animals' stalls will also contribute to these improvements.

In terms of location and space occupied, it can be concluded that the project will not require major immobilization of areas of the properties in any of its components and, therefore, the impact of occupying areas inside and outside the properties will tend to be contained and of low influence on the means and spaces of rural production. Even the biogas and biomethane production plants occupy relatively small spaces, considering the size of the pilot project already installed in the region. The possibility of locating the biogas and Syncrude plants in areas with already consolidated land use reduces the potential impact on native forests and environmentally sensitive areas.

In terms of the environmental risks posed by the biogas and methane plants and the Syncrude/SAF or Methanol plant, they are more related to the possibility of accidents with inputs, and the production of gases and fuels stored in significant quantities. Although they represent a significant potential impact, they are elements and manufacturing processes that could/should have constant and rigorous monitoring and control.

In addition, it is understood that the program documentation provides for the use of critical contaminants in manufacturing processes, which reduces the potential impact of the projects to the levels usually applied to standard manufacturing industries. The use of water resources is also considered to be within normal industrial limits and does not represent any significant risk of alterations to the availability of groundwater or surface water.

Although the Program projects actions and facilities that could have an impact on the environment and society, given the existing data and considering the conditions exposed by the available documentation, the conclusion is that the projects have positive environmental suitability. There is an interpretation that in the Primary Production Module, especially with regard to the agricultural production farms, the positive environmental and social impacts will tend to outweigh the negative impacts, defining full socio-environmental viability. With regard to the biogas plants and the Syncrude plant, although they may represent activities that have an impact on the environment due to their industrial nature, the expected changes to the physical and biological environment and the use of natural resources, it can be concluded that they are fully socially and environmentally viable due to the social benefits they will represent once they are up and running.

With regard to the Program's formal environmental viability approach, none of the elements presented in the documentation, data collection and analysis carried out indicate a risk that the projects will not be licensed. Therefore, from the formal point of view of environmental licensing, it is concluded that the Program is viable.

However, there are some risk elements that must be considered and worked out with the environmental agencies during the basic and executive design stages of the projects:

- The lack of specific regulations to guide the licensing of rural sanitation infrastructures. This aspect should be worked on by the developer together with the environmental agencies in order to establish clear and appropriate regulations to guide the licensing of rural sanitation structures/ducts on properties.
- The splitting up of environmental licenses due to the Program being structured into various undertakings organized into a system. Attention must be paid to the legal impossibility of fractioning or slicing up a project in order to obtain environmental licensing more quickly, in an attempt to provide a framework with a lower polluting potential. Fractioning the licensing process with this artifice is illegal and puts the entrepreneur at risk of embargo and fine.
- The time it takes to obtain full licenses. Biogas production plants, larger/extended pipelines and the Syncrude plant are classified as projects with high or great polluting potential, which determines full three-phase licensing, based on an EIA/RIMA and a mandatory Public Hearing. This level of complexity for licensing usually means a long time between the initial protocol, carrying out the environmental studies, submitting the documentation with the license application and issuing the licensing certificate, understanding the three phases of the procedural rite, which are LP, LI and LO. It is common for industrial environmental licenses to take between 1.5 and 3 years to be processed, which can be a challenge for certain entrepreneurs.
- The location of each project is fundamental for obtaining the Preliminary License. Although the civil engineering/construction solution often indicates the best location for a given structure or infrastructure, this is not always adequate in environmental terms. It is recommended that before starting basic projects for biogas plants and the Syncrude Plant (including power plants), consultation with the regulatory environmental bodies is carried out. It is recommended that the plants should not be installed in geographical areas of direct influence of trans-state or trans-national rivers (Paraná River), which is why they would be subject to more complex and time-consuming environmental licensing with IBAMA, as well as other bodies.

4.7.2 Final considerations on Greenhouse Gas Emissions applicable to the Green Fuels Paraná Program

When analyzing the *Green Fuels* Paraná Program in order to quantify the GHG emissions generated or avoided throughout its phases and processes, the following considerations can be made:

- The *Green Fuels* Paraná Program does not present the baselines of the production processes used to generate the raw material "animal waste" and this compromises all the analyses and results presented.
- The *Green Fuels* Paraná Program does not establish the technological boundaries of the processes analyzed, the scenarios constructed or the emissions considered in each of the *emission tiers*, which limits robust analysis and conclusions.
- The data presented in the materials of the *Green Fuels* Paraná Program does not present a theoretical methodological reference for the development of its approaches or the calculation methods used to determine the results presented.
- The values of the animal herds considered in the program present a static methodological approach, which differs from the approaches requested by the UNFCCC/IPCC international methodologies, which request the total calculation of animals according to their annual production systems, considering the effective production periods and disregarding the spaces for health gaps
- Data for fish and poultry farming is still insufficient to correctly determine their net emissions (generated and avoided).
- The emissions generated for the production of electricity from the different potential sources of electricity were determined using the official Brazilian government GHG Protocol platform, however, the resulting values do not represent the process boundaries.
- The GHG emissions figures for hydroelectric power and wind and photovoltaic sources are not explained by the GHG Protocol, raising doubts about the scope of the processes for defining each of the electricity sources. The GHG Protocol does not establish the life cycle of energy sources and does not specify whether the results take into account all their life phases: construction, implementation, generation, transmission, transformation and use. This methodological restriction may be the reason for the discrepancies between the results of these three so-called low-carbon sources of electricity.
- The *Green Fuels* Paraná Program presents opportunities for new production arrangements for waste management and technological innovation for the treatment and use of animal waste, which is a very positive factor. However, attention must be paid to the real socio-environmental benefits of these proposals, as other possibilities for private-private partnerships and public-private partnerships with good economic and socio-environmental attractiveness have already been observed in Paraná, involving rural producers, animal integration cooperatives and other companies.
- The results presented have varying uncertainty factors in their different phases, e.g. when determining emissions in anaerobic lagoons, the results for fish farming and poultry farming come from secondary information and data; the results for pig farming and cattle farming are more certain, as they are based on real data from the Sicredi Avoided Methane Program, but the figures for determining the static herd may have generated discrepant results.
- In order to correctly determine the net emissions from the production of Syncrude, SAF and methanol, specific data and information is needed on the inputs and outputs of each process and their resistance flows at all stages of the product's life cycle. For this study, the only fugitive emissions that could be taken into account were those from electricity consumption. However, as was observed, different sources of electricity generate different emissions and this determines the final balance of net GHG emissions from each system and its products, whether positive or negative in terms of reducing GHG emissions.

- It is necessary to consider all the system's emissions, both specific and fugitive, as they determine the final net emissions. This is why determining the baseline using methodologies valid under the UNFCCC/IPCC, VERRA and/or the Gold Standard is essential for any carbon or climate change project.
- Since the *Green Fuels* Paraná Program is considering the involvement of various social actors, raw material transport, storage, processing and use in different locations, it will be essential to establish the environmental, social and technological limits or boundaries of each process, reference flow and production phase of the final products to ensure the validity of the benefits.
- As a first approach to scenarios A, B and C, the program presents interesting net emissions results for the production of Syncrude and Methanol when the electricity sources are wind and photovoltaic. However, because it has not presented the methodological approaches, calculation methods and scientific basis validated by the UNFCCC/IPCC, it is not possible to reduce or eliminate the uncertainty factors in these calculations, which is why the validation and accuracy of its results and conclusions will require field studies to collect primary data and reduce the uncertainties in the results.
- This study also has strong limitations, as it was developed based on secondary data and, in order to reduce its uncertainties and make its results more robust and replicable, field studies, technological, environmental and social delimitations will be necessary to delve deeper into all the data and information in order to reduce or eliminate the uncertainties in its results.
- Since the only fugitive emissions that can be accounted for are those from EE, the Program needs to study and define alternative low-carbon energy options, such as wind and photovoltaics. But there is great potential for processing and using poultry waste (poultry litter) in the form of pellets and used as a source of thermal and electrical energy generation, as it has interesting calorific value data, and this technology reduces or eliminates the risks of soil and water contamination when this waste is disposed of directly on the ground.
- The technological proposals of the three scenarios are very interesting for contributing to the Brazilian and German NDCs, and could generate socio-environmental and economic benefits for all the players involved. However, it is important to establish solid criteria so that the rural producers, the surrounding communities and the societies that will host the Syncrude, SAF and Methanol processing plants really do have socio-environmental, political and economic benefits; and that they are not just fundamental contributors to an economic chain that is so strategic for Germany and Brazil.
- The results presented in Table 8 show the net balance of GHG emissions in the production of Syncrude and Methanol using photovoltaic and wind power sources. However, the hydroelectric power source reduces net GHG emissions and, in the specific case of methanol, generates negative results, meaning that methanol production from biogas from animal waste is negative and should be discarded.
- Furthermore, the lack of a baseline for the program's emissions and the failure to comply with UNFCC/IPCC methodologies compromise the qualification and possibility of confirming and replicating the results presented by the Green Fuels Paraná Program.

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5 ANIMAL WELFARE

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5.1 Initial phase: visiting local producers

On August 29 and 30, 2023, three rural properties and one slaughterhouse in the municipality of Toledo-PR were visited with the aim of recognizing the current animal welfare practices adopted by producers of broiler chickens, dairy cattle farming, breeding swine farming, and finishing swine farming.

1. Dairy farm

A. Location: 24°44'58.89"S 53°49'21.37"W

B. Owners: Mônica Tonello e seus irmãos

C. Property area: 53,18Ha

D. Uptime: 34 anos

E. Breeding system: semi-intensive, independent

F. Number of animals: 114, including 54 lactating cows, 01 bull, and the remaining animals are heifers for rearing, calves (sold for beef) and female calves (remain on the property for rearing).

G. Size of the feeding and handling shed (corral): 95.7m².

H. Total size of the pasture paddocks: 5.8 hectares.

I. Veterinary nutritional assistance: not available. The feed is purchased ready-made from cooperatives in the region.

J. Veterinary health care assistance: limited, only provided when requested by the owner.

K. Average daily production: 22 liters.

L. Destination of the dairy production: regional dairy (Lactobom).

M. Observations: Family-owned property with apparent difficulty in maintaining infrastructure and sanitary conditions for the herd due to the age of the owners (over 60 years old) and the accumulation of responsibilities, as the family has no hired employees. The cows were generally in good body condition, active, and comfortable with the presence of people and other animals (dogs and cats), suggesting a harmonious environment. Some lactating cows were observed to have moderate to severe hoof problems. Others no longer have all teats of the udder functioning, indicating a history of mastitis that was possibly diagnosed and treated inefficiently, leading to teat loss. The owners can perform one of the tests for mastitis detection (California Mastitis Test - CMT), which was conducted during milking on one of the cows. They reported rare occurrences of mastitis; however, no records or documentation were provided regarding medication use, individual animal production, mortality, births, and other zootechnical indices. The hygienic conditions of milking are reasonable, as the owners properly conduct pre-milking and teat cleaning; however, several teats end up touching the ground once the cow is milked out.

Figure 5-1 Natural Mating Paddock

Figure 5-2 Feeding and handling corral


Figure 5-3 Calves


Figure 5-4 Milking waiting area

Figure 5-5 Milking parlor entrance

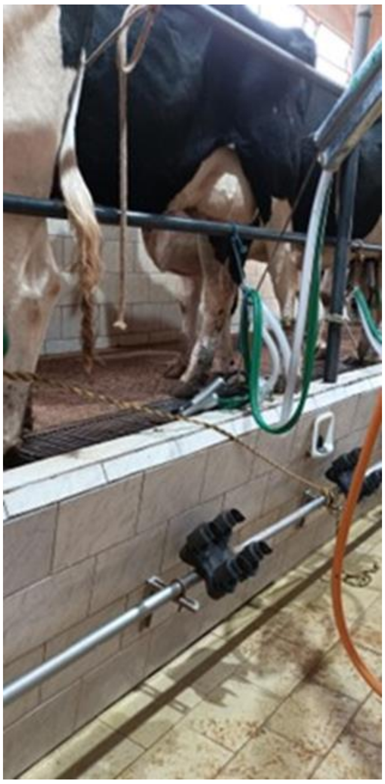

Figure 5-6 Milking room

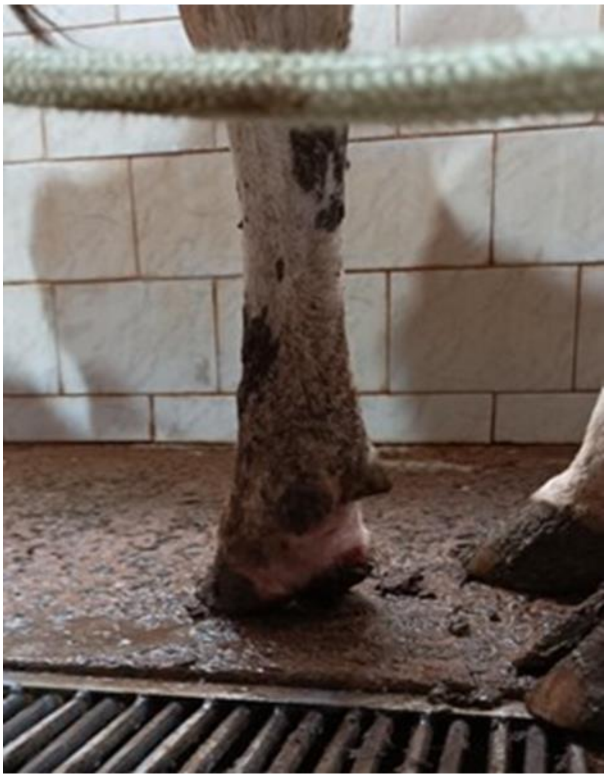
Figure 5-7 Injured hoof

5.2 Broiler poultry farm

A. Location: 24°44'58.89"S 53°49'21.37"W

B. Owners: Mônica Tonello e seus irmãos

C. Property area: 53,18Ha

D. Uptime: 36 anos

E. Breeding system: integration (BRF), conventional

F. Number of animals: 15,000

G. Shed size: 1,200 square meters.

H. Animal density: 12.5

I. Veterinary nutritional assistance: the responsibility of the integrator, which makes frequent visits to monitor the batch and adjust the nutritional levels in the formulation.

J. Veterinary health care assistance: the responsibility of the integrator, which conducts frequent visits and analyzes mortality data, its causes, causes of culling, and provides guidance to the producer.

K. Observations: The batch is slaughtered every 42-45 days. Zootechnical indices are well controlled by the integrator, the shed was organized, with no excessive ammonia odor. Due to cases of Avian Influenza in the state, we were not allowed to enter the housing and assess the structure and environment more thoroughly; however, the animals had good feathering, no signs of cannibalism, normal behavior, no crowding, with water and feed available.


Figure 5-8 View of the entrance to the poultry housing shed

5.3 Pig Finishing Farming

A. Definition: In this phase, piglets are at various ages (according to the batch), from the animal that has left the nursery (weaning) until the pigs are sold for slaughter.

B. Location: 24°45'10.33"S 53°48'12.36"W

C. Owners: Antonio Slongo

D. Property area: ????Ha

E. Uptime: 24 anos

F. Breeding system: integration (RPF), conventional

G. Number of animals: 2,900.

H. Size of the sheds and animal density:

I. Shed 01: 50m x 8.30m. Accommodates 340 finishing animals.

J. Shed 02: 100m x 12m. Accommodates 730 finishing animals.

K. Shed 03: 120m x 8.30m. Accommodates 926 finishing animals.

L. Shed 04: 130m x 8.30m. Accommodates 907 finishing animals.

M. Mortality: 0,5%

N. Transport of the animals: carried out by a specialized third-party company in the transportation of live pigs. The animals ready for slaughter can be directed to the slaughterhouse in the municipality of Bocaiúva do Sul, approximately 10 hours of travel and 580 km, or to the slaughterhouse in Ibiporã, approximately 430 km away, about 8 hours of travel.

O. Nutritional veterinary assistance: the responsibility of the integrator, which makes frequent visits to monitor the batch and adjust the nutritional levels in the formulation and management.

P. Veterinary health care assistance: the responsibility of the integrator, which conducts frequent visits and analyzes mortality data, its causes, causes of culling, and advises the producer on the use of antibiotics (mainly amoxicillin). According to the swine farmer, the most common disease is pneumonia.

Q. Observations: Swine farmers show a good openness to animal welfare principles and are willing to cooperate. They receive piglets at 55 days with an average weight of 20 kg. The animals stay on the farm until they are 90 days old, reaching a weight of approximately 115 kg. Daily management is conducted calmly, and the pens are assessed multiple times a day. Animals struggling to gain weight are relocated to another enclosure to prevent competition for resources and a decline in overall performance due to dominance of stronger piglets over more submissive ones. The natural ventilation system proved ineffective, as several animals were observed with respiratory signs, likely due to a noticeable excess of ammonia in the environment. Currently, the waste is used for fertigation in hay production for animal feed.

Figure 5-9 Housing for finishing pigs

Figure 5-10 Purification lagoon

5.4 Breeding swine operation

A. Location: 24°45'22.40"S 53°47'37.04"W

B. Owner: Ademir Geremias

C. Breeding system: integration (BRF), conventional

D. Number of animals: 2600

E. Mortality: 0,2%

F. Nutritional veterinary assistance: the responsibility of the integrator, which makes frequent visits to monitor the batch and adjust the nutritional levels in the formulation and management.

G. Veterinary health care assistance: the responsibility of the integrator, which conducts frequent visits and analyzes fertility indices (pregnancy rate, live births, weaning mortality), their causes, and provides guidance to the producer.

H. Observations: Reproduction farms, in general, do not allow visitors, and those who need to enter must go through a shower and change of clothes and footwear. For biosecurity reasons, we did not enter Mr. Geremias' farm, as on the same day, hours earlier, we had visited Mr. Slongo's finishing farm. Mr. Geremias' production is well-organized, with about 20 employees divided into work shifts, allowing 24-hour control of litters and sows, which explains the low piglet mortality rate. As it is a genetic dissemination farm, the replacement rate of sows is high. Each sow produces a maximum of two litters, meaning they stay on the farm for a maximum of 8-9 months, from insemination to piglet weaning. The organization of the farm is defined by the integrator, which collects culled females every 45 days and replaces them with other young females to keep the genetics always renewed. The culled sows are taken to the BRF's own slaughterhouse. The weaned piglets are transported from the nursery to finishing farms in the region. The same producer also owns another farm for male swine breeders that provide semen for the insemination of gilts in various breeding farms in Paraná. However, this property was not visited on August 29, 2023.


Figure 5-11 Photo of the breeding sows' housing shed (external view)

5.5 Slaughterhouse Bolson

A. Location: -24.762901872245255, -53.757045274510716

B. Number of slaughters per day: 800

C. Average emergency slaughters: 10 pigs/day

D. Number of condemnations due to bruises and fractures (partial or total): 20 pigs/day

E. Observations: They are initiating the formation of a team responsible for the well-being of the pigs in the holding pens and during slaughter. The difficulty is finding candidates who will stay with the company after training. Overall, the hygiene and sanitary aspects are excellent. The issue noted was during the stunning of animals before slaughter. Currently, stunning is done by electronarcosis, and not all animals are effectively stunned before bleeding. During the visit, we observed about 20 animals during slaughter, and at least 01 animal was not adequately stunned. The failure is relatively acceptable because this method of stunning requires a certain precision in the application of electrodes at specific points, and animals tend to become agitated in the stunning box. The slaughterhouse is investing in a piece of equipment called a "restrainer," whose purpose is to better restrain the animal and consequently reduce the chance of errors in the application of electric shocks.

F. Not allowed to take photos or record videos during the visit.


Frigorífico Bolson
Legenda
Baias de espera
Unidade industrial
Frigorífico Bolson
Google Earth
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5.6 Analysis of the answers from producers about animal welfare

In order to better understand the audience of the AW H2Uppp project, questionnaires were developed specifically for the farmers involved in the main activities carried out in the region, namely, the pig production chain, broiler poultry chain, and dairy cattle farming.

Given the complexity of the pig production chain, its structure is organized as follows: finishing pig farming, referred to as Finishing Units (UT); nursery pig farming, also known as Nursery Units (UC); piglet production farming, titled Piglet Production Units (UPL); and pig breeders, or Genetic Dissemination Units (UDG). Considering the similarity in the management of UPL and UDG, both received the same set of questions. Therefore, a total of five different questionnaires were developed, which are attached herewith.

The dissemination of the material was overseen by Mr. Mosconi, the director of MELE in Brazil, who, through regional WhatsApp groups, contributed 156 responses out of a total of 1,285 registered properties in the project. This represents a sample size of 10.8%. Among the 156 contributions, there were 90 UT producers, 28 dairy cattle farmers, 18 broiler poultry farmers, 10 UPL/UDG producers, and 10 UC producers, as depicted in Graph 1.

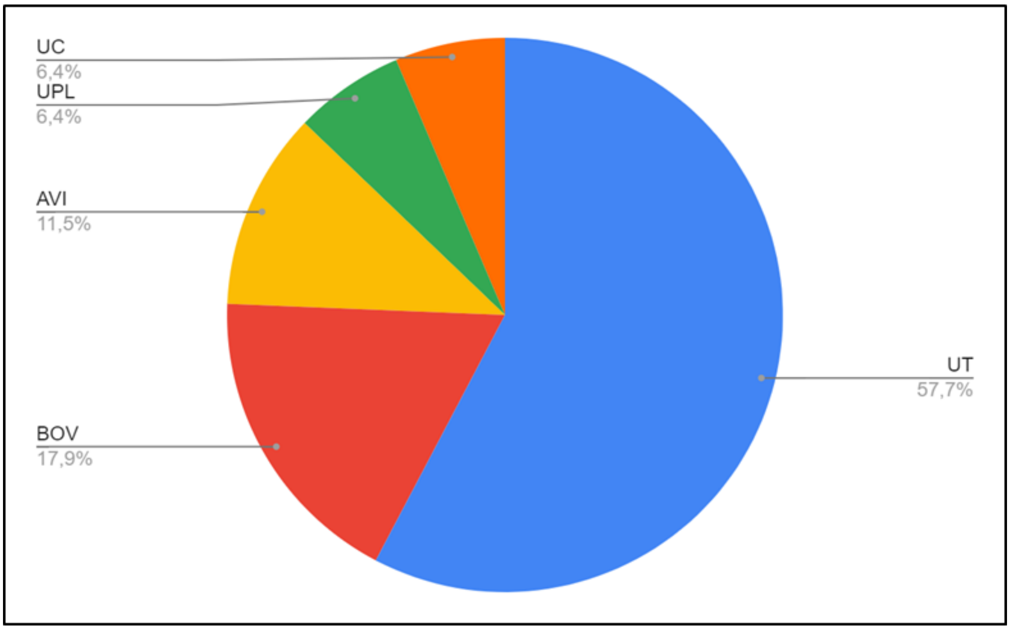

Figure 5-12 Graph 1 - Distribution of Livestock Activities

The majority of properties are small-scale family farms (Graph 2), as classified by Law 8,629 of February 25, 1993, amended by Law No. 13,465 of 2017. This legislation defines "smallholding" as a rural property with an area below the Minimum Parcel Fraction and "small property" as a property with an area between the Minimum Parcel Fraction and 4 fiscal modules. In Paraná, 1 fiscal module corresponds to 12 hectares.

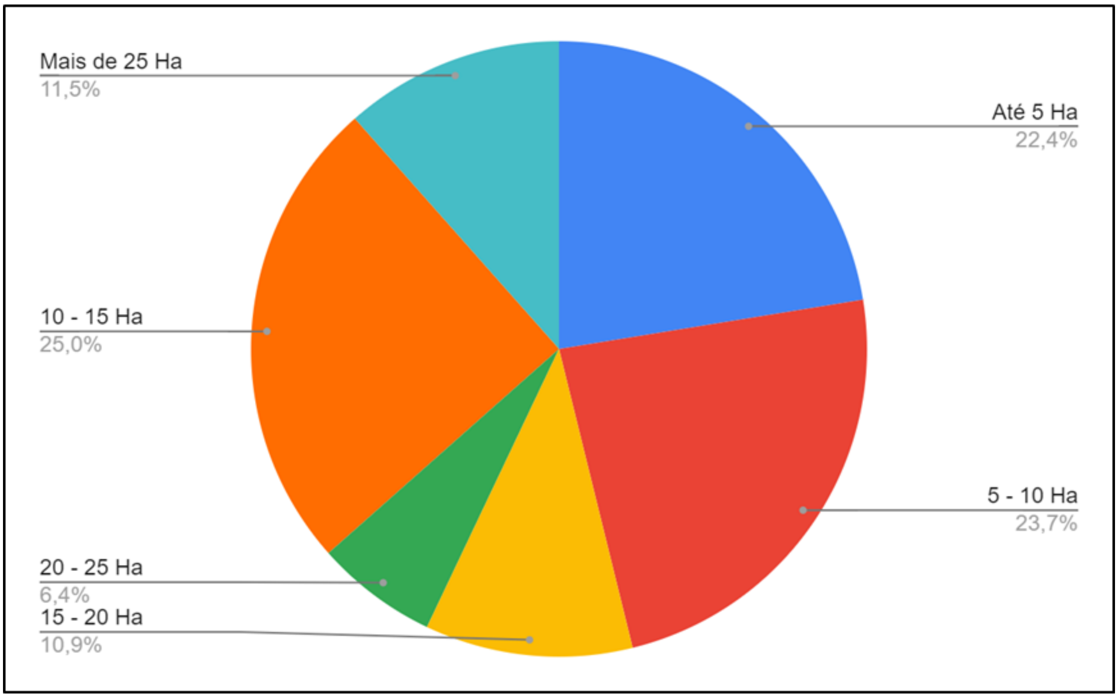

Figure 5-13 Graph 2 - Extension of Rural Properties

Regarding the families' experience in their respective activities, the majority, 68%, has been in the field for 10 to 30 years. This experience can be a relevant factor for animal welfare, as the producer's knowledge can aid in interpreting the animal's needs, preventing diseases, and adjusting management more efficiently, thereby enhancing the quality of life for the livestock. On the other hand, experience over time may lead to resistance to new production methods.

Table 5-1 Time Dedication per Livestock Activity

Atividade pecuária / Anos de trabalho	Avicultura de corte (%)	Bovinocultura leiteira (%)	UDG/UPL (%)	UC (%)	UT (%)
0-10	15	0	10	40	12,2
10-20	50	19,2	20	40	38,9
20-30	25	46,2	20	20	32,2
30-40	10	23,1	40	0	8,9
>40	0	11,5	10	0	7,8

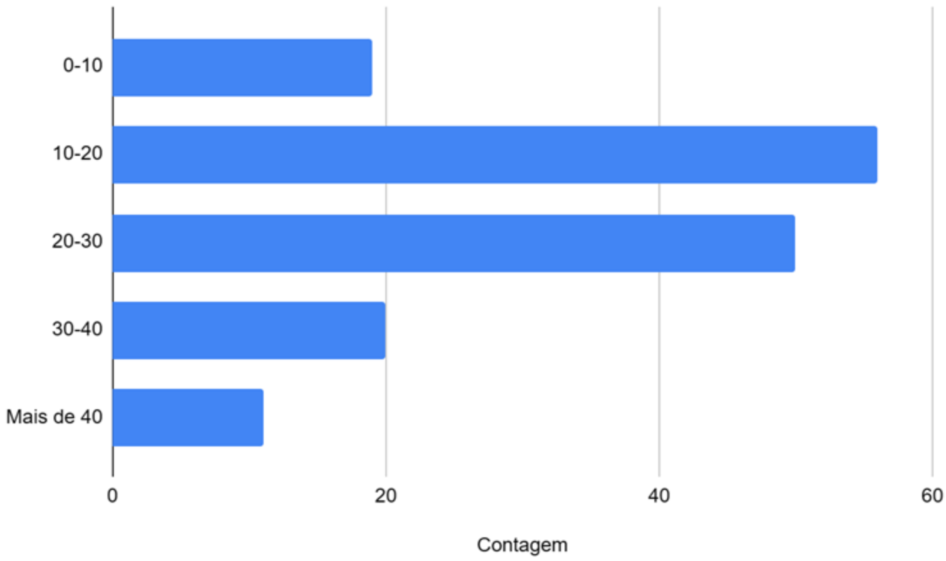

Figure 5-14 Graph 3 - Time dedication to Livestock Activity

Regarding the organization of producers in the production chains, the majority are part of integrators and cooperatives in the region, which can be beneficial, especially for reducing production costs related to animal feed and veterinary assistance, responsibilities typically handled by integrators. Additionally, integration provides more balanced remuneration parameters, as the contract shields market fluctuations on final product prices, a safeguard not afforded to independent producers. In poultry and pig farming activities, the vast majority are integrated, with 100% and 88%, respectively. Conversely, in dairy cattle farming, 75% of producers work independently, potentially ensuring greater decision-making power in their activities.

Concerning animal welfare indicators, producers answered questions about the breeding system in each livestock activity, animal density, mortality rate, causes of mortality, veterinary monitoring, use of medications, main diseases affecting herds, organization of animal transportation for slaughter (poultry and pigs), disposal of dead animals, daily waste generation, and the perceived air quality in the barns. Given that preventable diseases leading to animal deaths can be identified through these indicators, the analysis focused on this aspect.

Producers' responses regarding mortality rate, its causes, and the main illnesses affecting herds revealed similar scenarios for broiler poultry, finishing pig farming, and nursery pig farming. Respiratory diseases were the primary concern, likely attributable to poor air quality. Approximately 50.8% of participants reported discomfort due to ammonia odor, 37.5% claimed no discomfort, and 11.7% responded "maybe."

For piglet farming (including UDG), diarrhea was the leading cause of mortality, followed by respiratory diseases. Piglet diarrhea is primarily linked to sanitation issues, causing not only deaths but also hindering piglet growth and incurring medication costs.

In dairy cattle farming, the main reported disease was udder infection (mastitis), followed by tick-borne disease (parasitic sadness). Respiratory diseases were not mentioned by cattle farmers. Mastitis is multifactorial, with the main cause being lapses in sanitary animal management, encompassing equipment hygiene, personal hygiene of the milker, udder hygiene before and after milking, and environmental hygiene where the cows feed and rest.

The second most cited cause of mortality by poultry farmers was sudden death syndrome, also known as "chicken heart attack." This multifactorial ailment involves management issues, nutritional imbalances in diet formulation, and genetic factors related to rapid weight gain without corresponding cardiovascular development.

For finishing pig farming, the second most common cause of mortality was swine paratyphoid (commonly called "mixer"), causing characteristic respiratory symptoms, diarrhea, and skin lesions. This disease stems from sanitary management failures, such as inadequate facility hygiene, negligence with feed, and vaccine failures in sows, for example.

The second most prevalent ailment affecting piglets in the nursery phase was "runting syndrome," a viral infection causing immunosuppression and opening the door to secondary infections by other opportunistic pathogens. The disease can be prevented with proper nutritional care, good sanitary facility management, and other biosafety measures.

5.7 Workshop about one welfare

Based on the questionnaire responses, the training of rural producers on December 14, 2023, in Toledo took the form of a workshop. The first concept presented was the crucial idea of "one welfare," encompassing the interdependence of animal welfare, human well-being, and a balanced environment. The workshop illustrated the currently unfavorable scenario for the continuity of livestock activities, considering the low family succession due to the disinterest of new generations in rural work that has yet to fully integrate emerging technologies to facilitate work in livestock activities. Additionally, environmental imbalance becomes a challenging factor for the sustainability of agricultural production. The increasing visibility of animal welfare in recent years is of utmost importance for the sustainability of food production chains. Knowing that humans derive part of their sustenance from animal products within an environment conducive to expressing the selected genetics to their maximum potential, the stakeholders in this field have the responsibility and commitment to make choices aiming to ensure that the basic principles of animal welfare are respected. In doing so, economic viability of livestock operations is ensured, as animal welfare becomes a commercial concern, fair remuneration is guaranteed to producers who can increase income with added value, making the activity more attractive to new generations, and environmental mitigation is facilitated, with a reduction in medication use, resource savings, and circular economy practices.

Figure 5-15 Slide presented in the workshop about one welfare

Next, a video from the Federal Council of Veterinary Medicine (CFMV) presenting the principles of animal welfare was shown (https://youtu.be/rL9SWfPp3jk), followed by a brief presentation of Brazilian legislation and a comparison with laws in Germany. The discussions were intense as the topic is controversial, bringing to light weaknesses in systems that require changes in behaviors and cultures. The participation of women in the workshop was of great value, as they actively engaged and led discussions for a significant portion of the session. The main focus was on the lack of communication and connection between producers and integrators, which, according to them, could hinder the adoption of new practices and investments for animal welfare.

During the group dynamics, cardboard and pens were distributed to allow everyone to record their thoughts on what needs to change for animal welfare practices to be established. Among the responses, support from the government and integrators in infrastructure investments, improvement in animal genetic quality, finding ways to hold integrators accountable for animal welfare, especially during animal transportation, improving technical support for producers, and ensuring fair remuneration were highlighted.

5.8 Comparison of legal regulations in Brazil and Germany

In the member states of the European Union, animal welfare is applied according to animal welfare laws, legal regulations (directives), conventions, guidelines and practical recommendations. The European Directives issued by the European Commission act directly in the member states or are transferred in state laws without falling below the criteria and standards of the EU Directives.

The EU directives relevant for farming of livestock and chickens are:

Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes (OJ L 221, 8.8.1998, p. 23).

Council Directive 2008/119/EC of 18 December 2008 laying down minimum standards for the protection of calves (OJ L 10, 15.1.2009, p. 7).

Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs (OJ L 47, 18.2.2009, p. 5).

Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards on the protection of laying hens (OJ L 203, 3.8.1999, p. 53).

Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production (OJ L 182, 12.7.2007, p. 19).

A most important criteria in regards to animals in the EU is the statement in the EU constitution (2004, Art. III), that animals are “sentient beings”, underlining their status as co-creatures.

In Germany, the protection of animals is based on the European Community (EU) legislation, the German Animal Welfare Law (TierSchG) and on the German Constitution, which defines animal protection as a goal of the state (National goal of animal welfare). Article 20 a of the constitution says: „The state protects, also in responsibility for future generations, the natural foundations of life and the animals within the framework of the constitutional order through legislation and, in accordance with law and rights, through executive power and jurisdiction“.

The most important legal basis for the protection of farm animals and all other animals in practice is the German Animal Welfare Law (TierSchG) and the Ordinances. The most important and influential principles are laid down in paragraphs 1 and 2.

In §1 the purpose of the law is formulated: “The purpose of this law is to protect the life and well-being of animals based on human responsibility for animals as fellow creatures. No one may cause pain, suffering or harm to an animal without reasonable cause“.

Even more important is §2: „Anyone who keeps, cares for or has to look after an animal has the duty. (1) “The animal must be fed, cared for and housed appropriately for its species-specific needs, (2) must not restrict the animal's ability to move appropriately in such a way that it causes pain or avoidable suffering or damage, (3) must have the knowledge and skills necessary to provide appropriate nutrition, care and accommodation for the animal“. (Animal Welfare Act, 2006, BGBl. I p. 1207).

The status of animals in the German legal system was again strengthened by a change in the Civil Code in 1990 (German Civil Code, BGB, §90a. BGBl. I p. 1762), saying that animals are not “things” any longer. The § 90a states: “Animals are not things. They are protected by special legal regulations.

Brazil also has a long tradition in animal welfare. The first animal protection law in Brazil was passed back in 1934 under the Getúlio Vargas government (Decree 24.645 of July 1934), which was the first time that animals in Brazil were protected from perpetrators under threat of punishment. There is currently no animal protection law, as all more recent drafts have so far failed to gain a majority in parliament.

The new Brazilian Constitution (CF) of 1988 clearly shows that Brazilian society is moving towards greater animal protection. The protection of animals is enshrined in Article 225. According to this, all animals existing on Brazilian territory, whether small, farm, wild or laboratory animals, are protected by the constitution (Junior 2018; Mendes 2018; Silva and Gonçalves 2020; Timm et al. 2020).

However, the "extensive fragmentation" of animal welfare legislation makes it difficult to prosecute criminal offenses, meaning that there are only a small number of trials with convictions of perpetrator.

The reason is, different from Germany, that there are existing many directives, codes of practice and similar prescriptions on federal, state and municipal level which make it difficult to apply a common standard in the whole of Brazil. A large and almost comprehensive collection of all legal prescriptions in Brazil is given in two large volumes of the Compendium Animalis and Compendium Animalis, Anexos (Timm, S.; Hartung, J.; Maiorka, P. 2020, 2021).

Essentially, however, both sets of animal welfare legislation in Germany and Brazil have the same goal, namely to ensure the welfare of animals within all practical limits. The laws and legal provisions in both countries are designed to protect all animals, be they farm animals, small animals, wild animals or laboratory animals. An important difference between the two countries is that German animal welfare law is based on a uniform Animal Welfare Act of 1972 (in the version of 18.5.2006), which applies in all 16 federal states. There is no such centralisation in Brazil today. This will continue to be the case until the overarching Federal Animal Welfare Code (Código Federal de Bem-Estar Animal) or draft law (PL) 215/2007, which has been before parliament for approval since 2007, does not come into force.

The basic provisions for the protection of animals and plants (fauna and flora) can be found in the Brazilian Constitution (CF) of 1988, which states in Art. 225 § 1 VII: "Everyone has the right to an ecologically intact environment, common property of the people and essential for a healthy quality of life. Protecting and preserving it for present and future generations is the duty of the public authorities and the community. To enforce this right, public authorities are responsible for protecting flora and fauna. Practices that jeopardize their ecological function, cause the extinction of species or subject animals to suffering are prohibited by law" (Paul, 1989).

The German constitution (GG) also mentions the protection of animals and the environment as a state objective. As already mentioned above, Article 20a has stated since 2002: "The state shall protect the natural foundations of life and animals within the framework of the constitutional order through legislation and, in accordance with the law and justice, through executive power and jurisdiction".

This means that animal protection has been declared a state objective in both countries' constitutions with almost the same wording. The German definition emphasizes a bit more the “protection” of the animals as an obligation of the state. Therefore, Germany has an “Animal Protection Law” and not an “Animal Welfare Act” although both terms aim at ensuring the health and welfare of animals. The wording of the Brazilian Constitution underlines the protection of nature.

The definitions of what constitutes a farm animal are very similar in Brazilian and German law. The Brazilian definition of farm animals is listed in Art. 2 I of the implementing regulation (IN - Instrução Normativa) of the Ministry of Agriculture, Livestock and Supply (MAPA - Ministério da Agricultura, Pecuária e Abastecimento) 56/2008 on good practices for the welfare of farm animals:

- Animals whose husbandry purpose is to produce meat, milk, eggs, wool, hide, leather and honey or a product for commercial purposes. Furthermore, Art. 2 II defines animals of economic interest (e.g. horses) as “any animal which is considered to be a farm animal or which is kept for sporting use or for export sales and which generates income and employment”.

Largely similar formulations can be found in Section 2 Definitions of the German Animal Welfare Livestock Farming Ordinance (TierSchNutztV IdF der Bek. v. 22.8.2006), where Section 1 on farm animals reads as follows:

- farm animals and warm-blooded vertebrates which are kept for the production of food, wool, hides or skins or for other agricultural purposes or whose offspring are to be kept for these purposes.

The German Animal Welfare Husbandry Ordinance (TierSchNutztV) describes in large detail the housing and management conditions for the animals. This Ordinance has developed significantly over the last few decades. It is connected to the European Convention for the Protection of Animals kept for Farming Purposes (LwTierhÜbk) and to the EU directives laying down minimum requirements for the protection of farm animals.

There is no congruent (directly comparable) equivalent to the TierSchNutztV in Brazilian legislation. However, there can be found many parallels with IN MAPA 46/2011. This prescription contains specifications for the certification of livestock farms according to organic requirements (organic farms). In addition, there exist a number of so-called "good practices" (boas práticas), e.g. IN MAPA 56/2008. These standards do not have the force of a law but are helpful in practice.

Overall, when comparing the legal regulations on the minimum requirements for keeping farm animal species discussed here, the different volume and level of detail of the regulations in the two countries is striking. This may also be related to the structure of the regulations. In the first part of the German TierSchNutztV, information is initially provided that applies to all animal species covered by the regulation, followed by detailed regulations specific to the animal species. A similarly consistent level of detail as in the (TierSchNutztV) could not be found at the legal level in Brazil. This does not rule out the possibility that there may be specific instructions on animal welfare at company and farm level.

There is a significant difference in the monitoring and enforcement of animal welfare regulations in practice by the competent authorities.

The execution and surveillance of the animal welfare act in Germany is carried out in practice by the local competent authorities, usually the veterinary offices in land districts and towns. These offices keep close contact with prosecutors of the state in case of severe violations of the law and suspected criminal acts. Spot checks e.g. in farms can also be carried out by expert teams from state level (Länder) institutions (e.g. LANUV, LAVES).

5.9 Conclusions and Recommendations

When comparing the legal regulations on the minimum requirements for keeping the farm animals discussed here between Germany and Brazil, the difference in volume between the two sets of regulations is obvious.

However, the initial and tentative comparison of legal regulations in the field of animal welfare based on the farm visits and on literature studies reveals many similarities between both countries and also differences in some areas.
The existing gaps must be narrowed and finally closed.

This is a central and complex task, which must be carried out by an expert team, which have to be composed from both sides, the Brazilian as well as the German side. Farmer’s organizations should also be included or at least consulted.

This task cannot be performed until the end of year 2023, when the H2Brasil Project officially ends. Drawing up efficient training programmes requires considerable effort, expertise and time.

In the project, it seems useful to keep contact with the respective farms by questionnaires (as already initiated and executed in a first round by Amanda Peniche and a short checklist of production, health and welfare data following the five Animal Welfare Principles.

In the future, aspects of occupational health (worker health) should also be addressed.

The project should also serve for a better understanding of the arguments, ways of thinking and conditions in the field of animal welfare in Germany and Brazil.

Training of farmers in animal welfare issues should be provided, both in legislation and in practice, by means of classroom teaching in groups and practical, instructive teaching on the farm. Such capacity building is crucially important for the project and future of farming in the area.

To carry out effective teaching and training on farms in the Toledo/Palotina region, it would be helpful to have available an environmental/animal welfare laboratory established on the Palotina Campus (UFPR), possibly next to the H2 laboratory there. There, analytical instruments for environmental, occupational and animal welfare assessments can be stored, maintained, repaired (if necessary) and disinfected between field operations. Besides, The National Rural Learning Service (SENAR) of the Faep system can be of great assistance for training programs.

An animal welfare self-assessment procedure, which can easily and fast be carried out by farmers themselves several times during the year should be developed and implemented that as many of the 1700 farmers as possible could be included.

The Bavarian self- assessment model could be adapted and used. Later for evaluations, the German OS standards (QS system) could be a useful scheme to measure the success of the initiatives.

The animal welfare team should closely cooperate with farmers, stakeholders, industry, other experts and governmental bodies in both countries.

Crucially important for the success of the H2Brasil Project is to consider the sustainability of the entire supply chain for the products resulting from the project. That is especially important for the German consumer. That means, also environmental questions should be included in future.

The science-based approach of the project should be continued, which will help to make the international position of Brazil and Germany in the field of animal welfare more visible.

5.10 References

German Civil Code, BGB, §90a. BGBl. I p. 1762, 1990

EU Welfare Quality Project, 2012

Nascimento and Marisco 2017

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6 ECONOMIC AND FINANCIAL MODELING RESULTS FOR THE E-METHANOL PROJECT IN PARANÁ

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6.1 Theoretical Framework Unit Operations for the Biorefinery

This study will provide a detailed description of the process involving the key unit operations simulated to secure financing for biogas production in 45 production centers, and for the biorefinery aimed at producing biomethanol and green hydrogen. The unit operations have been divided into essential transformation stages that constitute the system starting from biogas.

6.1.1 Processes - Biogas into Syncrude

6.1.1.1 Base case (without recycles)

The first process configuration proposed was defined as the base case for the conversion of biogas into syncrude, without considering any recycling for comparison purposes.

This process begins with the biogas upgrading section (water scrubber), that separates the CO2 and CH4 streams. The CH4 stream is mixed with water (in a final proportion of ~1.92 steam/CH4) and sent to the SMR. The resulting syngas stream is blended with the CO2 from the biogas upgrading step, after adjusting the CO2 to the desired pressure and temperature conditions. This mixed stream is then converted in the RWGS reactor (adiabatic post-converter), achieving a CO2 conversion of 44 %. The obtained syngas passes through a series of heat exchangers for cooling and further dehydration, with the water removal at the bottom of a flash tank. The resulting syngas stream still retains a considerable amount of CO2, that must be removed before the FT stage. For this purpose, a MEA absorber system is employed, and subsequently, the syngas temperature is adjusted before it is sent to the Fischer-Tropsch reactor. The hydrocarbons produced in the FT reactor are gradually cooled and separated in flash tanks. As previously mentioned, since no recycling is considered in this simulation, after the final separation of the syncrude fraction, a stream with a mass flow rate of 18,367 kg/h is obtained, containing both unreacted syngas and light hydrocarbons. This reference process is presented in a block flow diagram with main information of mass balance presentation.

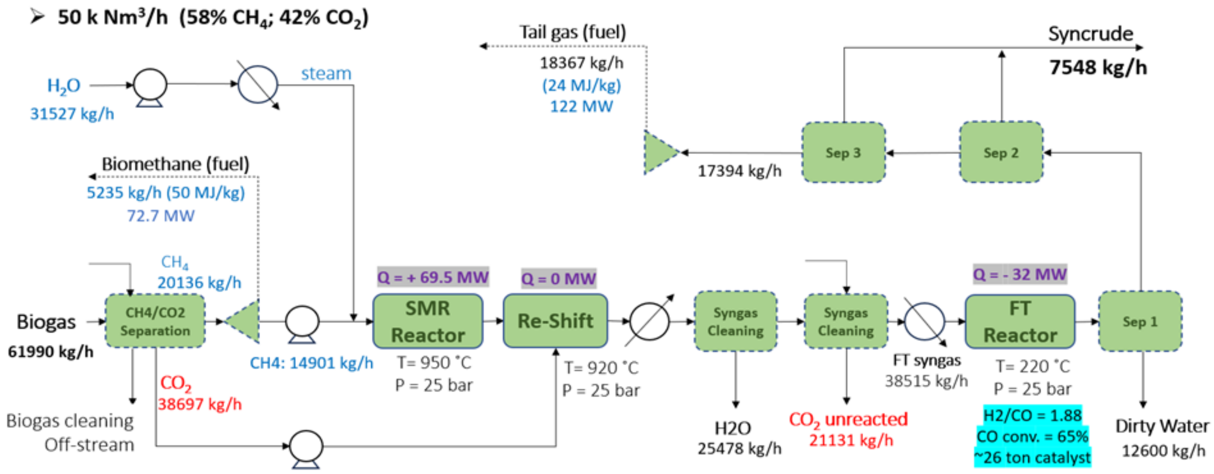

Figure 6-1 Block flow diagram for the base case process evaluated – biogas conversion to syncrude.

6.1.2 Technological option A - Process 02 - Base case (+ recycles)

Considering that in the base case a significant quantity of unreacted syngas was obtained, a second analysis configuration was proposed with tail gas recycling. This adjustment promotes the syncrude final production and prevents the loss of the compounds within this stream. To ensure an effective recycle of tail gas, which comprises amounts of light hydrocarbons other than methane, an additional unit operation, namely the pre-reformer, is required.

The main structure of the process remains the same as the one outlined in scenario

01. Until the product separation step, after the FTS, the unit operations align with those previously detailed. However, in this case, after separating the stream containing the unreacted syngas and light hydrocarbons from syncrude, it is necessary to include a pre- heating step and a pre-reformer to convert these light hydrocarbons, excluding methane, into syngas. One more notable difference between the two processes described is that in process 02, steam is introduced directly into the pre-reformer instead of the SMR. Following the pre-reformer, a portion of the stream containing the unreacted CH4, combined with the produced syngas, is blended with the fresh methane from the water scrubber before entering the SMR reactor. In this configuration, the resulting S/C ratio at the SMR inlet stands at 1.1, with a CH4 conversion of 70.6 %. The CO2 conversion in the RWGS reactor is approximately 46 %. In process 02, a significant 90 % of the tail gas stream resulting from the FT product separation is successfully recycled, leaving only 4,134 kg/h of tail gas excluded from the recycling loop. The amount of tail gas not reintroduced into the system is considerably lower compared to scenario 01, resulting in an enhanced process productivity. This remaining tail gas could be utilized as a fuel source in furnaces, for instance.

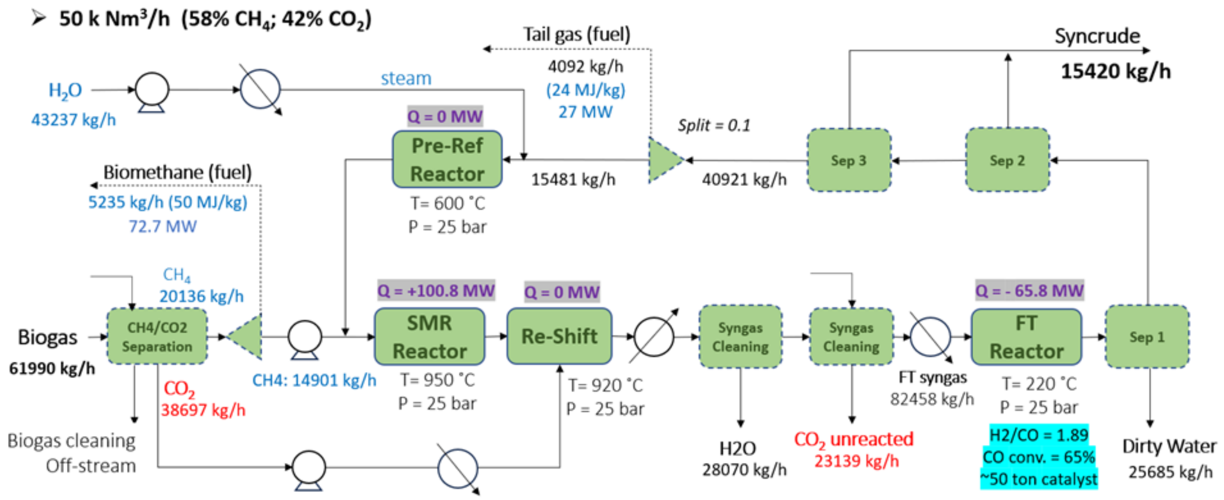

Figure 6-2 Block flow diagram for the base case with tail gas partial recycling – biogas conversion to syncrude.

6.1.3 Technological Option B - Process 02 - Base case (+ recycles + RWGS)

As it was previously mentioned, in both process 01 and 02 the unreacted CO2 from the Re-Shift step needed to be removed from the syngas prior to the FT synthesis. This task was accomplished by the MEA system, which effectively eliminated this compound, but necessitated the purging of CO2, causing a negative impact on the process sustainability and productivity. In response to this issue, process 03 was proposed to address the unconverted CO2 by incorporating an additional RWGS reactor.

In this scenario, the CO2 stream exiting the MEA system is pre-heated and directed to a RWGS reactor, where it is converted to syngas. This intermediate product is combined with the one generated by the SMR, and the resulting process stream is then sent to the FT reactor. This configuration will increase the syncrude production and reduce the CO2 emissions, but due to the significantly larger syngas stream, more catalyst will be required in the FTS stage, affecting the process total cost. In practice, all the CO2 could be recycled in the process simulations. In this case, the steam to methane ratio in the SMR was 1.12, with a CH4 conversion of 71.3 %. Also, the CO2 conversion was 42.5% and 76 % in the Re-Shift system and in the RWGS reactor, respectively.

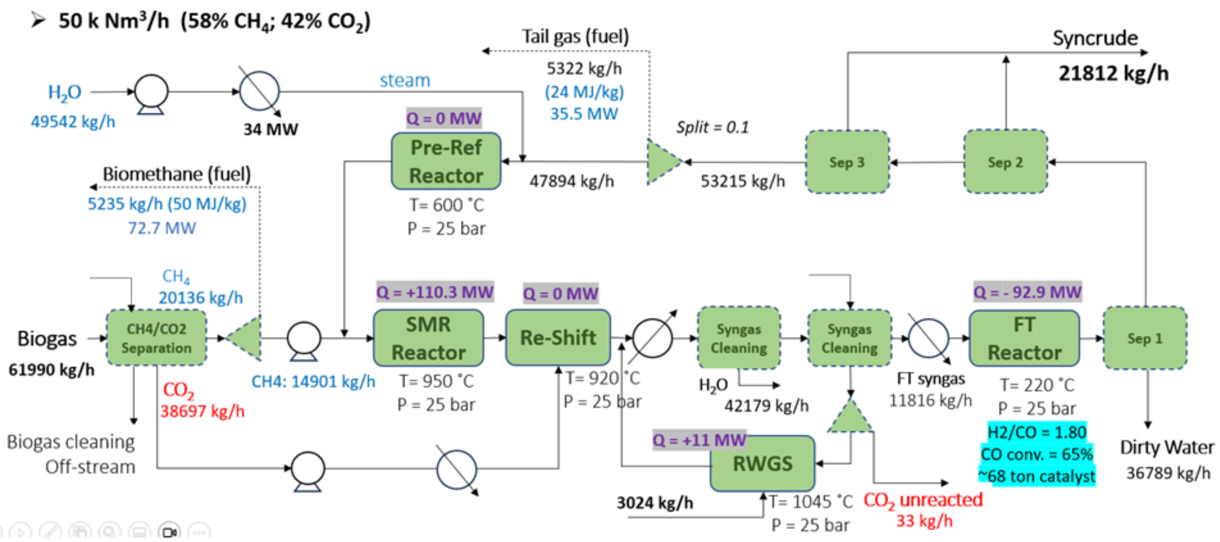

Figure 6-3 Block flow diagram for the base case with tail gas partial recycling – biogas conversion to syncrude

6.1.4 Comparison - Syncrude processes

Table 6-1 Analyzed operational parameters for comparison among the configurations.

Parameter	Process 01	Process 02	Process 03
Syncrude production	7,548 kg/h	15,396 kg/h	21,802 kg/h
H2/CO molar ratio	1.88	1.88	1.80
S/C molar ratio	1.92	1.10	1.12
Unreacted CO2	21,131 kg/h	23,145 kg/h	33 kg/h

CAPEX estimative was performed for these three cases evaluated using two Order- of-Magnitude Estimate methods, as presented in Tables 3.2 and Figure 3.4 (Seider et al., 2017).

Table 6-2 Estimated CAPEX for the proposed configurations using Method 1: Order-of- Magnitude Estimate (based on the Method of Hill) (Seider et al., 2017).

Parameter	Process 01	Process 02	Process 03
Module Cost	$15,630,811.65	$21,990,495.07	$32,948,157.04
Total bare-module Investment	$51,701,915.45	$72,737,791.38	$108,982,365.60
Direct Permanent Investment	$113,744,214.00	$160,023,141.03	$239,761,204.32
Total Permanent Investment	$170,616,321.00	$240,034,711.54	$359,641,806.49

Total Capital Investment (CAPEX)	$196,208,769.15	$276,039,918.27	$413,588,077.46

Another quick methodology to make an order-of-magnitude estimate of plant cost is to scale it from the known cost of an earlier plant that used the same technology or vendors published data. This requires no design information other than the production rate. The capital cost of a plant is related to capacity by the scale equation, as indicated in Fig. 3.4 applied for those three different processes evaluated for syncrude production from biogas. For these estimates have been considered as base-plant a Fischer-Tropsch plant and a Gas-to-Liquids process (Towler & Sinnott, 2021).

Process 01

Rapid Cost Estimates

Method 2: Order-of-Magnitude Estimate (Reference Plants Capacity)

Towler & Sinnott (pag. 249)
Acurracy: +/- 50%

The quickest way to make an order-of-magnitude estimate of plant cost is to scale it from the known cost of an earlier plant that used the same technology or from published data. This requires no design information other than the production rate.
The capital cost of a plant is related to capacity by the equation

$$C_2 = C_1\left(\frac{S_2}{S_1}\right)^n$$

$$C_2 = \frac{C_1}{S_1^n} \times S_2^n = a\ S_2^n$$

Syncrude (Our case)

	7500 kg/h			
FT Plant	45000 ton/yr	295 mi U$S	2006 Index	
		503 mi U$S	2022 Index	
GTL Plant	1660.4 bbd	195 mi U$S	2006 Index	
		332 mi U$S	2022 Index	

CE Index 2006	478.6
CE Index 2022	816

Process	Licensor	Capacity Units	S_{lower}	S_{upper}	a	n
Fischer Tropsch Process	ExxonMobil	tpy	200,000	700,000	0.476	0.6
Fluid catalytic cracking	KBR	bpd	20,000	60,000	0.210	0.6
Fluid catalytic cracking with power recovery	UOP	bpd	20,000	60,000	0.302	0.6
Gas to liquids by Syntroleum Process	Syntroleum	bpd	30,000	100,000	2.279	0.6
Gas sweetening by Amine Guard FS to pipeline spec	UOP	MMscf/d	300	800	0.386	0.6

Process 02

Rapid Cost Estimates

Method 2: Order-of-Magnitude Estimate (Reference Plants Capacity)

Towler & Sinnott (pag. 249)
Acurracy: +/- 50%

The quickest way to make an order-of-magnitude estimate of plant cost is to scale it from the known cost of an earlier plant that used the same technology or from published data. This requires no design information other than the production rate.
The capital cost of a plant is related to capacity by the equation

$$C_2 = C_1\left(\frac{S_2}{S_1}\right)^n$$

$$C_2 = \frac{C_1}{S_1^n} \times S_2^n = a\ S_2^n$$

Syncrude (Our case)

	15500 kg/h			
FT Plant	93000 ton/yr	456 mi U$S	2006 Index	
		777 mi U$S	2022 Index	
GTL Plant	1969.4 bbd	216 mi U$S	2006 Index	
		368 mi U$S	2022 Index	

CE Index 2006	478.6
CE Index 2022	816

Process	Licensor	Capacity Units	S_{lower}	S_{upper}	a	n
Fischer Tropsch Process	ExxonMobil	tpy	200,000	700,000	0.476	0.6
Fluid catalytic cracking	KBR	bpd	20,000	60,000	0.210	0.6
Fluid catalytic cracking with power recovery	UOP	bpd	20,000	60,000	0.302	0.6
Gas to liquids by Syntroleum Process	Syntroleum	bpd	30,000	100,000	2.279	0.6
Gas sweetening by Amine Guard FS to pipeline spec	UOP	MMscf/d	300	800	0.386	0.6

Process 03

Rapid Cost Estimates

Method 2: Order-of-Magnitude Estimate (Reference Plants Capacity)

Towler & Sinnott (pag. 249)
Acurracy: +/- 50%

The quickest way to make an order-of-magnitude estimate of plant cost is to scale it from the known cost of an earlier plant that used the same technology or from published data. This requires no design information other than the production rate.
The capital cost of a plant is related to capacity by the equation

$$C_2 = C_1\left(\frac{S_2}{S_1}\right)^n$$

$$C_2 = \frac{C_1}{S_1^n} \times S_2^n = a\ S_2^n$$

Syncrude (Our case)

	23500 kg/h			
FT Plant	141000 ton/yr	585 mi U$S	2006 Index	
		997 mi U$S	2022 Index	
GTL Plant	2985.8 bbd	277 mi U$S	2006 Index	
		473 mi U$S	2022 Index	

CE Index 2006	478.6
CE Index 2022	816

Process	Licensor	Capacity Units	S_{lower}	S_{upper}	a	n
Fischer Tropsch Process	ExxonMobil	tpy	200,000	700,000	0.476	0.6
Fluid catalytic cracking	KBR	bpd	20,000	60,000	0.210	0.6
Fluid catalytic cracking with power recovery	UOP	bpd	20,000	60,000	0.302	0.6
Gas to liquids by Syntroleum Process	Syntroleum	bpd	30,000	100,000	2.279	0.6
Gas sweetening by Amine Guard FS to pipeline spec	UOP	MMscf/d	300	800	0.386	0.6

Figure 6-4 Capital costs estimated of the three different processes using a Magnitude-order estimate based similar plants and scales

Significant differences are evident when comparing the processes performances among processes 01, 02 and 03, regarding various parameters. Progressing from process 01 to 02 and then to 03, there is an increase in process complexity and the utilization of by-products. Consequently, syncrude production shows a notable rise of 104 % in scenario 02 and 189 % in scenario 03 when compared to scenario 01. Since the H2/CO molar ratio in the FT reactor inlet remains relatively constant, a similar FT performance is expected.

Additionally, in processes 01 and 02, since the unreacted CO2 removed from the syngas is purged from the process, a substantial quantity of this compound is released into the atmosphere, potentially affecting the process sustainability. Conversely, in scenario 03, only a negligible amount of CO2 exits the process.

The process sustainability, productivity and complexity will inevitably impact the process economics. When compared to scenario 01, scenario 02 exhibits considerably higher costs, primarily attributed to factors such as larger equipment, some additional equipment (e.g. pre-reformer) and an increased catalyst consumption. The same cost escalation is evident in scenario 03, where costs are even higher costs due the inclusion of the RWGS reactor. Moreover, the catalyst mass within the FT reactor reaches 55 tons, leading to a larger syncrude production. The recycling stream and the equipment prior to the FT reactor are also affected by this larger catalyst amount, resulting in an overall higher cost for this scenario.

6.1.5 Suggested Range of Capital Costs (CAPEX)

Thus, gathering the information obtained from these estimates it is seen that these processes might vary in a wide range of values (see Table 3).

Table 6-3 Estimated CAPEX for the proposed configurations using Method 2: Order-of- Magnitude Estimate (based on plant scales) (Towler & Sinnott, 2021).

Planta/processo base	Processo 01	Processo 02	Processo 03
ExxonMobil FT Plant	503 MM US$	777 MM US$	997 MM US$
GTL Plant	332 MM US$	368 MM US$	473 MM US$
Method 1 (Table 3.2)	196 MM US$	276 MM US$	414 MM US$
Total Capital Costs (Suggested range)			
Minimum Cost Suggested	196 MM US$	276 MM US$	414 MM US$
Maximum Cost Estimated	503 MM US$	777 MM US$	997 MM US$

Note: All these numbers must be considered with +/- 50% accuracy.

6.1.5.1 OPEX - Operational Expenditure

An initial estimate for the operational costs (OPEX) was conducted for the three analyzed scenarios. It considered electricity consumption for pumps and compressors, the acquisition of raw materials (in this case, exclusively biogas), the water supply and the utilities costs associated with heat exchangers. It is worth noting that the heat exchangers potentially involved in heat integration schemes were not included into this utility estimation.

The considered prices for water and electricity were based on current rates from suppliers in Paraná state: 11.06 R$/m^3 for water (AGEPAR, 2023) and 0.366 R$/kWh for electricity (COPEL, 2023). The exchange rate applied in the calculations (US Dollar to Brazilian Real) was 5.05 USD/R$ and the biogas price was estimated at 0.6 R$/kg.

For the first scenario, only water was considered as a cooling utility. All the heat exchangers that required heating fluids will likely to be integrated into heat integration networks. The cooling water utility was introduced into the process at room temperature (25 ˚C) and 26 bar, to align with the steam conditions of the reforming processes. This allowed the heat exchangers to serve as pre-heating equipment for steam generation. Also, in this process configuration, only three water streams were required, totalizing approximately 161 tons per hour, that exits the process at 214 ˚C. Given that the volume of cooling water significantly exceeded the amount of steam needed in the reforming reactor, no additional water consumption was considered in the reformer, as the pre- heated water could be partially employed to generate steam. This assumption is valid for the three observed scenarios.

The configuration outlined for scenario 02 is similar to the one described for scenario 01, with the exception that high-pressure steam is needed for heating purposes in a specific heat exchanger. In this scenario, which takes into account tail gas recycling, the heating and cooling requirements of the streams were higher, resulting in a greater demand of cooling water (298 tons/h). The hot water exits the process at 118 ˚C, a considerably cooler temperature than in scenario 01. The decrease in this parameter can be attributed to the higher demand of water in the recycle streams for cooling purposes. As a result, the water temperature was raised to a lesser degree, considering the available heat within the process.

Finally, in the third scenario, similar to scenario 02, there was a requirement of high-pressure steam in a heat exchanger. Moreover, the streams associated with both the inlet and outlet of the additional RWGS reactor were integrated into the heat exchanger network. In this instance, the water utility stream achieved a temperature of 147 ˚C before exiting the process.

The pre-heated water stream resulting from the three processes could be considered, for example, for steam generation, to be either used internally in the process or to be sold to improve process economics. This steam generation could be performed in a boiler with some remaining amount of tail gas or biomethane from the process. Steam selling was not considered at this point. The general results obtained for the three process scenarios are summarized in Table 3.

Table 6-4 OPEX Comparison

Scenario	Unit	Processo 01	Processo 02	Processo 03
Electricity Consumption	MW	3,67	3,63	3,63
Electricity Costs	$/h	266,22	263,10	263,10
Water Consumption (process)	tons/h	0,72	0,72	0,72
Water Costs (process)	$/kg	1,58	1,58	1,58
Water Consumption (utility)	tons/h	160,57	316,94	358,89
Water Costs (utility)	$/h	352,42	696,51	788,40
HP Steam Consumption (utility)	tons/h	-	18,47	24,14
HP Steam Costs (utility)	$/h	-	40,46	52,88

Biogas Cost	$/h	7365,17	7365,17	7365,17
OPEX	$/h	$7.985,38	$8.326,35	$8.418,24
OPEX (without raw material)	$/h	$620,22	$961,18	$1.053,07

In all the analyzed cases the biogas greatly contributes with the OPEX. Furthermore, disregarding the OPEX contributors estimated based on the CAPEX (e.g. maintenance) and considering only the analyzed variables, the difference in the OPEX for the three analyzed cases is not much pronounced considering the difference in process productivity. The observed difference is mainly due to the increased water consumption as a cooling utility. A more detailed OPEX estimation needs to be performed considering other important variables such the ones previously mentioned, that consider the CAPEX value, such as the maintenance. These variables could have an impact in distinguishing the OPEX of the three scenarios. Despite this, it can be observed that the initial estimation could be performed only by considering simple, non-toxic and relatively cheap utilities such as water and steam. When considering the OPEX without raw material, another important contributor is electricity since significant amounts of gas need to be compressed to the reforming pressure at the beginning of the process.

Considering all the proposed scenarios, scenario 02 (which involves a percentage of tail gas recycle, but not the use of CO2 in a new RWGS section) is indicated as the most suitable for the production of syncrude from biogas. The productivity combined with the acceptable values of CAPEX and OPEX and the profitability of the process as a whole show an economically viable alternative for Fischer-Tropsch synthesis, with a focus on SAF production.

6.1.6 Process 04 – Biogas into Methanol

An alternative pathway for biogas utilization involves its conversion to methanol via a three-step process: steam methane reforming, water-gas shift, and methanol synthesis. This method features a high 91% recycle of unreacted components, similar to the syncrude production process.

Appendix IA-B presents the process flow diagram implemented in this work for considering the technical feasibility and the preliminary economic assessment.

This process begins with the biogas upgrading section (water scrubber), that separates the CO2 and CH4 streams. The CH4 stream is mixed with water and sent to the SMR. The resulting syngas stream is blended with the CO2 from the biogas upgrading step, after adjusting the CO2 to the desired pressure and temperature conditions. This mixed stream is then converted in the RWGS reactor (adiabatic post-converter), achieving a CO2 conversion of 55 %. The obtained syngas passes through a series of heat exchangers for cooling and further dehydration, with the water removal at the bottom of a flash tank. Subsequently, the syngas temperature is adjusted before it is sent to the methanol reactor.

The product stream obtained in this step contains a mixture of unreacted syngas, CO2, CH4, water and methanol. Post-reactor, a heat exchanger takes on the role of cooling the system and condensing water and methanol. Subsequently, the chilled mixture is directed into a distillation column. Remarkably, the distillation process removes 98.5% of the water in the bottom stream. However, the inclusion of a partial condenser results in the generation of two distinct product streams.

The vapor stream, laden with unreacted syngas, CO2, CH4, and trace amounts of methanol, is reintroduced into the system to enhance the conversion of methanol synthesis. This stream undergoes compression to 70 bars, achieving an impressive 91% recycle rate. Meanwhile, the liquid stream, comprising water, methanol, and dissolved CO2, undergoes additional processing. A strategically valve expands the mixture, facilitating the removal of CO2. Ultimately, a flash tank separates the remaining water and CO2 from the purified methanol, yielding a main product with a purity of 98.5%.

6.1.7 Economic Analysis Methodology - Biogas into Methanol

Understanding the economic feasibility of a project is essential in engineering proposals, and different methodologies can be utilized for this analysis. To analyze the economic feasibility of the methanol production process from synthesis gas, there are three available methods: order of magnitude estimation, the Lang Global Factor method, and the Guthrie Individual Factor method. The latter was chosen since it provides errors in the order of 20 %. Meanwhile, the other two do not guarantee such a reliable result, bringing errors in the range of 35 %.

The Guthrie method was initially developed by Hand, and later improved by Guthrie himself (in 1969). According to this concept, it is possible to estimate the Total Invested Capital (CTCI) of a plant, through equation (1). Each parameter in the cost estimation model will be discussed above.

$$C_{TCI} = 1{,}18 \cdot \left(C_{TBM} + C_{site} + C_{buildings} + C_{facilities}\right) + C_{wc} \qquad (1)$$

The Total Invested Capital (CTCI) can be split into depreciable and non-depreciable capital. The Total Depreciated Capital of an investment is the cost related to equipment that wears out according to its expected lifespan. This means that all assets that have natural loss of value suffer a depreciation of their value. Consequently, after 10 years (on average), their cost will be very small in relation to the purchase value. This variable includes the costs of acquisition and installation of equipment (CTBM), the cost of area preparation (Csite), the cost of general installations (Cbuildings), and the cost of utility installations (Cfacilities).

When a certain asset does not suffer physical wear and tear over time, its value at the end of its use remains the same as it was at the beginning of its use. Therefore, it does not suffer depreciation and can be sold for its market value or even more. This capital is called non-depreciable, and it will be considered as the working capital or the start-up costs (CWC). Each cost associated with the Total Invested Capital (CTCI) will be described individually.

- Total Module Cost (CTBM)

CTBM sums up bare-module costs for every process equipment element, from tanks and machinery to computers and software. The bare-module cost of each equipment (CBM) starts with the base price of the equipment (CFOB), then adds in the cost of materials and labor needed to install it (direct field costs), and finally includes additional expenses like shipping, insurance, and overhead (indirect expenses).

$$C_{BM} = C_{FOB} \cdot F_M \qquad (2)$$

CFOB is the cost of the equipment calculated with freight and insurance separately, as the transportation of the goods is the responsibility of the buyer. This cost is calculated using the correlations and values established by Guthrie (1974) and Seider et al. (1999), correlations which are different for each piece of equipment. In addition, FM is the module factor for correcting this FOB cost and varies according to the unit operations.

Table 6-5 Module factors for different equipments

Equipments	F_M
Horizontal reactors	4,3
Columns	4,3
Heat Exchangers	3,3
Centrifugal Pumps	3,4
Compressors	3,5

Adapted from: (Seider et al., 2009).

The module prices are calculated and estimated in dollars for a CE index equivalent to 560.4 at the end of 2010. Therefore, it is necessary to correct these values using the following relationship:

$$C_{2023} = C_{210} \cdot \frac{C_{2023}}{C_{2010}} \quad (3)$$

For 2023, the Chemical Engineering Plant Cost Index used was 798.7. This value is available on Chemengonline, of Chemical Engineering (https://toweringskills.com/financial-analysis/cost-indices/). Also, a safety factor of 20% was added in the total bare-module cost.

- *Site Cost (C_{site})*
  Site preparation and development costs (C_{site}) can be significant for new plants (grass-roots plants), ranging from 10 to 20% of the total bare-module cost of the equipment (C_{TBM}). However, for an expansion of an existing integrated facility, the cost is typically much lower, falling between 4% and 6% of the C_{TBM}.
- *Buildings Cost ($C_{buildings}$)*
  The cost of process buildings can be initially estimated at 10% of C_{TBM}. For new plants (grass-roots plants), non-process buildings can be preliminarily estimated at 20% of C_{TBM}. However, for expansions of existing integrated complexes, non-process buildings are typically lower at around 5% of C_{TBM}.
- *Facilities Cost ($C_{facilities}$)*
  Offsite facilities encompass utility plants (if the company manages its own utilities), pollution control systems, ponds, waste treatment facilities, offsite tankage, receiving and shipping infrastructure. Additionally, an estimated 5% of CTBM can be allocated for other offsite facilities.
- *Working Capital (C_{WC})*
  Working capital, beyond fixed and startup costs, bridges the gap between a company's payments and receivables. It covers operational needs like inventory and accounts receivable. Accountants measure it as current assets minus liabilities, including cash, inventory, and receivables on one side, and accounts payable on the other. Typically, a one-month buffer is provided, reflecting standard 30-day payment terms for both purchase and sale of goods. It can be calculated by:

$$C_{WC} = cash\ reserves + inventory + accounts\ receivable - accounts\ payable \quad (4)$$

Each variable can be defined as follows.

Cash reserves: to cover expenses such as raw materials, utilities, operations, maintenance, overhead, property taxes, insurance, and depreciation, a 30-day buffer of cash reserves is required. This equates to 8.33% of the annual cost of manufacture (COM), assuming a 30-day period represents one-twelfth of a year. The annual cost of manufacturing (COM), which is consider as the OPEX value, is the sum of the direct manufacturing costs (that includes feedstocks, utilities, labor-related operations, and maintenance), the operating overhead and the fixed costs (property taxes, insurance, and depreciation).

Inventory Working Capital: A seven-day supply of liquid and solid products is held at the sales price, assuming weekly shipments. This represents 1.92% of annual sales for liquid and solid products only.

Accounts Receivable: Thirty days' worth of product receivables are held at the sales price, amounting to 8.33% of annual sales for all products.

Accounts Payable: The company maintains a thirty-day buffer for feedstock payables at the purchase price, representing 8.33% of annual feedstock costs.

6.1.8 CAPEX and OPEX estimations

The results calculated for the CAPEX of the methanol plant are available in Table
2.6. It is important to mention that the CAPEX from renewable plants is described in Chapter 4. The results calculated for the OPEX of the methanol plant are available in Table 6.6.

Table 6-6 Total CAPEX investment costs

Description	Value (US$)
Total Module Cost (C_{TBM})	$ 350.762.624,87
Working Capital Cost (C_{WC})	$ 52.521.011,63
Site Cost (C_{site})	$ 52.614.393,73
Buildings Cost ($C_{buildings}$)	$ 70.152.524,97
Facilities Cost ($C_{facilities}$)	$ 114.478.376,73
Total Capital Invested Cost (CTCI, equation 32)	$ 746.370.357,58
CAPEX from renewable plants	$ 652.000.000,00
Total CAPEX Investment Costs	$1.398.370.357,58

Table 6-7 Total OPEX investment costs

Description	Value (US$)
Raw Material Costs	$ 58.815.407,58
Utilities Costs	$ 100.981.048,20
Labor-Operations Costs	$ 341.141,30
Maintanence	$ 62.446.441,14
Depreciation	$ 44.701.188,91
Taxes and Insurance	$ 6.938.493,46
Total OPEX Costs	**$ 233.275.085,94**

While the analyzed biogas-to-methanol conversion case shows a similar C_{TCI} to previously presented ones, renewable plants like those in the next chapter have significantly higher CAPEX estimates. This increase mainly results from additional equipment, working capital, scale, and associated utilities. Notably, site, building, and facilities costs are based on the total module cost, further escalating with higher equipment costs. To isolate the operational aspects of the process, the OPEX and sensitivity analysis in this work did not incorporate the capital expenditure (CAPEX) associated with the renewable energy plants.

A detailed analysis of OPEX contributors was performed, aiming to identify the optimal utilities for key equipment like heat exchangers and reactors. While further refinement is required, the focus was on readily available, non-toxic, and cost-effective options like water and steam. However, due to the high-water demand of some heaters, heating oil was investigated as an alternative utility. To account for potential inefficiencies and operational cycles, a 5% loss factor was incorporated into the annual production cost/OPEX estimation. The analysis revealed that electricity was the primary contributor to OPEX due to the significant energy requirements of gas compression and electrolyte operation. This emphasizes the importance of optimizing these processes for improved energy efficiency, ultimately leading to reduced overall operating costs.

Regarding the specific OPEX parameters, it is important to mention that the labor- operation cost was estimated based on a general plant. Also, the maintenance was considered as 9% of all the depreciable capital calculated previously (C_{TCI}, equation 32), the taxes and insurance were 1% of this same capital and the depreciation was 8% of the difference between the C_{TCI} and 118% of the facilities costs ($C_{facilities}$).

6.2 Toledo Biogas Project - Green Fuels Paraná Program

6.2.1 Introduction

The Green Fuels Paraná Program is a technical extension of the SUSTAINABLE WEST PROGRAM, which aims at the management, treatment, and transformation of waste from agricultural and agribusiness activities in 18 municipalities in the West of the State of Paraná. This program is implemented by the private sector with the support of institutions and public bodies, aiming at mitigating greenhouse gas emissions.

One of the main objectives of this study is to present a business model for mitigating greenhouse gases through biogas production by anaerobic digestion, mainly using waste from the animal protein production and industrialization chain in the 18 municipalities of Western Paraná. The global planning is structured from the detailed planning, licensing, and legal structuring of the first management, treatment, and transformation center for biomass in the Rocio Community, in the Municipality of Toledo, for the final obtaining of electricity, biomethane, and liquefied CO_2, products to be used by cooperatives and agribusinesses in the animal protein production sector.

The model will be replicated in the 18 municipalities of Western Paraná, with the potential for expansion to other regions of the country, contributing to the Brazilian energy matrix with renewable energy sources and waste reuse. This study aims to demonstrate the potential for biogas production through animal waste from more than 6,000 animal protein production units in the 18 municipalities of the Western Paraná region. The waste from the production units will be collected and sent to centralized biodigestion units for biogas production.

45 centers are planned within the Program's territory, with an effluent collection rate of approximately 800 to 1,500 cubic meters per day (m^3/day) at each of the receiving, treatment, and transformation centers.

This process of biogas generation in centralized units will allow a significant reduction in CAPEX and OPEX, enabling this large volume of generated biogas to be connected by a gas pipeline network to a single treatment and transformation unit. With an estimated volume of over 50,000 m^3 of biogas per hour, this biogas can be converted into new products such as biomethanol or biosyncrude. The centers will allow the utilization of digestate for use as biofertilizers, produced after the treatment of anaerobic digestion residues.

This study considers the potential for mitigating environmental impacts and its capacity for large-scale biogas production. It is noteworthy that this conception, planning, and development of the program for managing, treating, and transforming residual biomass from the animal protein production and industrialization chain, is unprecedented in the country, and is characterized as an innovative project with potential for replicability in other locations in the country. Key characteristics of the Rural Sanitation Subprogram with Biogas and Biofertilizer production, which make it innovative and unprecedented:

- First conception of centralized projects for managing, treating, and transforming residual biomass from the animal protein production and industrialization chain, with a collection system for the liquid part through pipelines or rural sanitation network, with cogeneration system, composting, and utilization of digestate for fertigation, and the solid part being used for the organic granulated fertilizer production industry, which in turn will be used in planting and cultivating vegetable crops for vegetable protein production to be used as raw material in the formulation of animal feed for the animal population in the region;
- Great potential for the model to have a catalytic power and motivate and incentivize similar initiatives in other regions of the country, encouraging the private sector to engage strongly in this business modeling;
- Significant potential for mitigating environmental impacts and generating income for producers and investors;

- Promotion of self-sufficiency in food and energy consumption, biofuels, and fertilizers for producers in the region;
- Collective participation in the Program via Cooperatives, which allows for economies of scale and collective benefits and advantages;
- Structuring of the business model with family participation and intensive involvement of women;
- Biomass collection network, minimizing transportation costs and impacts;
- Social and participatory interaction of members in shared benefits;
- Sharing of Program benefits and advantages, meeting the collective demand for electricity from pig production units;
- Encourages unity and solidarity among members to promote the common good and business development for all participants.

It is expected that this study can contribute as an important reference source for the dissemination of biogas production projects in Brazil and worldwide. The technical support provided by GIZ through the PPP signed on January 16, 2023, and the Cooperatives formed - AMBICOOP, COOPERSAN, COOPERPONT, and COOGESMAR, are enabling positive results on multiple fronts such as: strengthening actions for program development, raising awareness about the cooperative's mission's importance for regional sustainability, and recognition of strengthening the local economy, as well as disseminating knowledge and promoting international partnerships. The activities carried out and the implementation of the first project by the AMBICOOP Cooperative in the Rocio community in Toledo, with the support and promotion from GIZ, directly impact the dissemination of the Green Fuels program and the legal model via cooperatives, enabling the repercussion and dissemination of the knowledge built in this phase and the promotion of sustainable practices. Some of the benefits that can be cited and highlighted from GIZ support include the following:

- Recognition of the program in structuring and implementation: the studies and implementation of the first unit of the Program will allow the Cooperatives and the Program to receive greater visibility and recognition for their practices
- Innovation benefits: The innovative practices can enhance the reputation of the program and attract new investments.
- Expanded target audience: Publishing the studies and the first project of the Program (Rocio Bioenergy Center in Toledo) is expected to attract a larger and more diverse audience interested in sustainable practices within the Green Fuels Paraná Program in the territory of the 18 municipalities of Western Paraná, initiating engagement with similar initiatives.
- Learning for other organizations: Publishing the studies and the establishment of the First Central of the Program will allow other organizations to access valuable information about the project, enabling the replication of successful practices in other contexts.
- Strengthening credibility: The publication of the studies will reinforce the image of the Program and the cooperatives involved as organizations committed to sustainability, aligned with the goals of sustainable development, governance actions, and innovative practices, generating more credibility and trust among stakeholders.
- Contribution to sustainable development: The implementation of this first stage of the Program, specifically regarding the Rocio Central project of AMBICOOP, can inspire other organizations to adopt more sustainable practices, contributing to the sustainable development of their communities and expediting the necessary mitigation actions on the global climate agenda.
- Access to new markets: The studies and the implementation of the first Central will open doors to new markets that value sustainability, allowing cooperatives and companies involved to explore new business opportunities and increase profitability.
- Strengthening international partnerships: By making the studies developed by different groups of the Program known and with the start of the implementation of the first Rocio Biodigestion Center in Toledo,

these associated factors will contribute to strengthening the international partnerships of the actors involved in the Program, enabling the exchange of experiences and collaboration with organizations and funds from other countries supporting sustainable initiatives.

The business model in the form of producer cooperatives, structured by the company MeLe Biogas, for the supply of biomass – essential raw materials for the biogas plants – will strengthen the bond among the cooperatives: the commencement of construction activities and the dissemination events of the conducted studies will have a positive impact on the self-esteem of the cooperatives, as it recognizes the work and joint effort towards biogas projects. This can strengthen the unity of the cooperatives, increase the engagement of each collaborator in the cooperative, contribute to improving the work environment, and accelerate the adherence of other communities that follow the same methodology to promptly address the appropriate disposal of their farm liabilities and transform these residual biomasses into revenue.

Local recognition of the planned concept of rural sanitation through the cooperative segment: the completed studies made public, associated with the constructive start of the first Rocio Central, will contribute to the recognition of the importance of cooperatives in waste management, rural sanitation, improvement of the quality of life of cooperatives, and impact on public health in the region. This will generate more support from the local population and public authorities for the implementation of new cooperative centers structured and to be structured in the region of the 18 municipalities of Western Paraná, focusing on energy transition, decarbonization, circular economy, and initiatives to strengthen rural producers in Western Paraná.

Furthermore, the recognition of the importance of cooperatives and the centralized concept of residual biomass treatment will encourage the emergence of new cooperatives in other regions of the country. The total estimated CAPEX as per the report of Product I of the PPP, of 548,048,584.20 euros, inclusive of taxes, without the incidence of taxes the estimated CAPEX becomes: 467,106,805.12 million euros. It is intended for 99% financing.

The suggested modeling is as follows: the final off-takers of the process should be the guarantors of the operation and risk. MeLe would manage all construction of the infrastructure for this phase of the Program. After each plant is completed, a leasing contract is entered into for that specific plant. To settle the CAPEX of that specific plant, the cooperative will exclusively sell the generated biogas to the off-takers at a proposed value of 0.0498 euros per kWh or 0.2988 cents per euro Nm^3 of biogas injected into the grid. With this monthly revenue, the cooperative will retain part of the biogas revenue to fulfill and pay the leasing installment.

The leasing operation, to settle the CAPEX value of each of the 45 plants, the sanitation networks they comprise, the two fertilizer industries, and the two composting plants, is planned for a duration of 15 years. At the end of the 15 years, the plants and the entire infrastructure complex implemented in Phase One of the Program will be fully owned by the cooperatives. The off-takers may also foresee a participation in this phase, which cannot exceed 30% due to the concept and Brazilian cooperative legislation.

The duration of the partnership between biogas production and the obligation of exclusive sale and commercialization to the economic group that will fund all CAPEX is planned for a minimum period of 25 years, extendable for more years.

6.2.2 Legal Model: Cooperatives for Sustainable Energy Generation and Rural Sanitation

Among the ways to develop and implement projects related to the use of biogas, the following legal structures can be considered in general terms: the creation of a corporation, the establishment of partnerships, and the creation of limited liability companies.

The structure of Cooperatives for Sustainable Energy Generation and Rural Sanitation is a private legal entity of a civil nature, singular, formed by the union of individuals for economic purposes, nonprofit, with limited liability, and governed by statutory provisions and current legislation.

The planned plants managed by the cooperatives, in close cooperation with Me Le Biogas, are governed not only by statutory norms but also by the legal framework formulated in the contract between the parties, as part of their community and entrepreneurship initiatives, aiming for the common good and environmental, social, and governance sustainability of the Cooperatives themselves and the region where they operate.

The mutual cooperation system was proposed due to the characteristics of the region and to ensure social and economic growth and to engage all stakeholders in a long- term reciprocal commitment, integrating waste collection collectively and producing the necessary biogas and fertilizers for the chain, thus allowing benefits and results for the entire community in this format.

It is believed that the adopted model represents the will of the community and aims at the sustainable development of the entire region of the macro Program.

Already established cooperatives and their objectives:

- AMBICOOP Cooperative – CNPJ: 41.826.293/0001-48
    - President of the Board of Directors: Ilmo Werle Welter
    - Headquarters - Toledo, PR.
- COOPERSAN Cooperative – CNPJ: 45.395.432/0001-87
    - President of the Board of Directors: Joemir Joao Oliveira
    - Headquarters - Nova Santa Rosa, PR.
- COOPERPONT Cooperative – CNPJ: 51.990.218/0001-71
    - President of the Board of Directors: Celito Acelino Rauber
    - Headquarters - Quatro Pontes, PR.
- COOGESMAR Cooperative – CNPJ: 52.345.869/0001-71
    - President of the Board of Directors: Fabio Knaul
    - Headquarters - Marechal Cândido Rondon, PR.

These cooperatives were established based on the collective will and desire of a significant part of the rural producers in their respective municipalities, with the purpose of structuring a collective solution to the issue of waste (organic residues) existing in agricultural production units and small agribusinesses in the region.

The main objectives of the Established Cooperatives are:

- Generating electricity from renewable sources;
- Manufacturing organic-mineral fertilizers and compost;
- Conducting anaerobic treatment of waste and biomass resulting in biogas production;
- Implementing composting plants for the treatment and transformation of green waste and organic residues;
- Providing services for the collection of non-hazardous waste;
- Providing services for the treatment and disposal of non-hazardous waste;

- Planning, constructing, and operating in partnership, gas and fertilizer production plants for supply to members, for remote self-consumption, or for commercialization;
- Treating the waste generated in the agricultural production chain of their members' production units, transforming them into renewable energies through the:
- Processing of biogas and organic fertilizers to be consumed or marketed among its members or also for the cooperative's self-consumption.
- Planning, constructing, and operating individually or in partnership, cogeneration units and/or biofuel production units, for supply to members or for self-consumption.
- Planning, constructing, and operating individually or in partnership, solar energy production plants for supply to members or for remote self-consumption.
- Planning, constructing, and operating in partnership agricultural production units and biofuel and green hydrogen commercialization units.
- Structuring new economic matrices by transforming environmental liabilities into economic assets (CO2e plants, biomethane production, bioenergy, solar plants, wind plants, organic fertilizer, among other possibilities).
- Promoting the generation and sharing of electricity or remote self-consumption through the production of solar, wind, or bioenergy derived from the treatment of waste from agricultural and agribusiness activities.
- Entering into technical and operational cooperation agreements with other cooperatives, as well as with other national and international public and private entities.

6.2.3 Sources of Funding for the Project

The initial part of the studies on biogas potential, legal model structuring, structuring of the first 4 rural sanitation and renewable energy generation cooperatives, executive projects of the first Rocio central, acquisition of the first two land areas for the implementation of the first plants, totaling approximately 3 million euros, was financed by the companies Me Le Biogas and Greentrx. The feasibility studies of the processes after this initial phase are being carried out in close cooperation with GIZ through the signing of a PPP, in which Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH provided a contribution of 478,400 euros through the H2Uppp Program. The additional expenses of the First Rocio Biodigestion Plant, the first of 45 planned, with projects and other fees for the completion and approval of projects, are being funded by the company Me Le Biogas Brasil and H2V - companies contracted to manage the construction and operation of the first plant. The machinery, equipment, and civil works of the first plant will be financed by BRDE Bank with resources from the Climate Fund. Considering the nature of the project, BRDE is interested in studying the feasibility of carbon credit instruments as part of the guarantees. For financing the development of executive projects and other complementary studies for the implementation of the other 44 plants, composting plants, and fertilizer industries, the necessary resources are shown in the table below:

Table 6-8 Calculations in Euros.

Operations in Euro	%	Total EURO
Capex Total	100%	548.048.584,20
Tax exemption envisaged	14,77%	80.941.779,08
Projected Capex after tax exemption		467.106.805,12
Financing operation, 15-year grace period for capital repayment		
OWN Capital	1,00%	4.671.068,05

6.2.4 Description of the Technical Model per Cooperative

Evaluation of the technical feasibility of the planned solution

For the evaluation of the technical feasibility of the biodigestion plants and complementary structures, strategic points of the implementation methodology, startup, and operation, technically feasible, were considered.
The analysis involves various technical aspects, including the availability of raw materials (supply of organic waste), processing capacity, necessary infrastructure, and energy efficiency. Four technical aspects are essential:

- The availability of raw materials is crucial for the technical feasibility of biodigestion plants with biogas production. The plant operator must have access to a stable and reliable source of organic waste to ensure continuous biogas production. It is important to understand the dynamics of agricultural activity, as well as to develop contractual tools that can consider the entire aspect of waste suppliers, in order to reduce the risks of supply shortage.
- Processing capacity is another important factor to be considered in the technical feasibility assessment. This includes the capacity to process organic waste, storage capacity at the biodigestion plants, delivery capacity of plant products, and especially the technical capacity of the operational and planning teams.
- The necessary infrastructure for the implementation and operation of biogas production plants is also evaluated, including the need for storage facilities, processing equipment, purification equipment, and transportation of the produced biogas.
- Analysis of the energy efficiency of the plants, with the aim of ensuring high productivity rates, with high performance, efficiently and profitably, considering aspects such as yield, production costs, and return on investment time.
- Constantly measuring and evaluating the potential environmental impacts of the entire process to ensure that the process will convert an activity with high environmental liability into an economic asset.

Advantages of anaerobic treatment and benefits of biogas production plant implementation:

- Ending inappropriate waste disposal,
- Eliminating risks of soil contamination and contamination of sources of potable water supply
- Contribute to the sustainable production of the animal protein chain
- Enable more sustainable grain production, with the availability of organic fertilizer produced at the Biogas Plant.
- Ensure significant environmental improvements
- Enable significant improvement in the socio-economic condition of rural producers.
- Expansion of the pig farming chain with environmental security
- Increase in tax revenue to Municipal Coffers
- Practicality in the renewal and/or issuance of environmental licenses by regulatory agencies.
- Consolidation of new economic models
- Future possibilities in replacing the energy matrix of agricultural production with the substitution of diesel oil by biomethane.

6.3 Specific Purpose Entity (SPE)

6.3.1 Analysis of Advantages, Disadvantages, and Risks of SPE

Naturally, there are advantages and disadvantages to establishing an SPE, just like any other business model. Analyzing the pros and cons is important before opting for this structure.

It can be said that the greatest advantage of SPEs is the security and transparency that their establishment provides to investor partners, as it is an autonomous legal entity with its own corporate structure, activities restricted to the project described in the corporate purpose, and financial flow entirely dedicated to such activity.

Thus, there is evident gain in competitiveness due to greater operational agility and cost reduction throughout the project.

Through the establishment of the SPE, each project or venture can have administrative, financial, and operational autonomy, not to be confused with other business activities potentially developed by its investor partners, which significantly mitigates operational risks.

This is because each SPE will have its own cash flow, employees, service providers, obligations that cease to exist immediately at the end of the project.

In summary, the advantages of establishing an SPE can be indicated as:

- Greater security and transparency to investor-partners with diluted risk;
- Greater control of cash flow and financial results;
- Greater agility in operation and project completion;
- Competitive gains in the market;
- Reduction of operational costs.

It is also worth mentioning that the SPE can adopt a different income tax calculation regime from that adopted by the partners, and, to date, there is an exemption from income tax on the distribution of profits and dividends to the partners.

Despite this, a disadvantage that should be considered before opting for the SPE business model is the fact that financial losses and risks cannot be offset by the partners' profits in a Specific Purpose Entity.

Furthermore, there is joint liability among the partners up to the limit of the capital stock of the project object of the SPE.

6.3.1.1 Advantages

Advantages are points that determine an SPE as a good choice for different purposes. See the list with the main ones:

- Models: It is possible to establish an SPE through any type of company (limited, joint- stock company, etc.). This flexibility makes the business applicable across different ranges.
- Profits and dividends: Profits can be distributed as dividends. Additionally, they may be exempt from income tax.
- Risk reduction: The SPE has financial and legal separation. Thus, the resources designated for that contractual purpose are isolated and do not suffer or influence other activities of the involved companies.

6.3.1.2 *Disadvantages*

Despite the mentioned benefits, SPEs also present challenges that must be considered. Some of the main risks and disadvantages associated with an SPE include:

- Complexity and structuring costs: Establishing an SPE requires the drafting of a detailed founding contract, addressing all relevant aspects of the project. This can be complex and require the participation of lawyers and specialized consultants, which can increase project costs.
- Coordination and decision-making: Coordination and decision-making among the partners or shareholders of the SPE can be complex, especially in long-term projects. It is essential that the founding contract of the SPE clearly establishes the rights and obligations of the parties involved to avoid future conflicts and disputes.
- Responsibilities and obligations: Companies participating in an SPE may be liable for obligations and liabilities that were not initially foreseen. It is important that the founding contract of the SPE provides mechanisms for the allocation of profits and losses to avoid unpleasant surprises in the future.
- Financial and operational risks: SPEs may be subject to financial and operational risks, such as project execution delays, cost increases, changes in legislation or the market, among others. It is essential that partners or shareholders carefully assess the risks associated with an SPE before deciding to participate in the project.

There is one main disadvantage that should be considered. Even though it is small in quantity, this factor is crucial before deciding on your business model.

- No compensation: Financial losses and risks cannot be offset by the profits of the partners in a Special Purpose Entity.

6.3.1.3 *Risk Reduction*

The structure of an SPE enables the financial and legal separation of a venture within the framework of a large company.

Imagine a large construction company with various lines of business, debts, and different sources of cash generation.

In this scenario, risks are multiplied since management could allow a healthy venture to be influenced by another one facing financial difficulties.

By establishing an SPE, the flow of resources for the project is isolated, as well as its guarantees and debts, without the influence of any external problems.

6.3.1.4 *Tax Cost Reduction*

The structure of an SPE also allows for the optimization of the tax structure.

Imagine a scenario where a venture is in the portfolio of a large construction company and needs to follow the taxation regime applicable to the company based on total assets, profit, and revenue, without necessarily being the most advantageous for the business.

When this venture is separated from the complex structure of the company in the formation of an SPE, it gains flexibility to optimize tax payments.

6.3.1.5 *Financial Cost Reduction*

The increased business security of the company within the SPE structure implies a series of secondary benefits.

For example, it is easier to raise funds through debt issuance or bank loans with reduced financial and legal risks of the structure.

In this setup, the company can leverage the venture being constructed, for instance, as collateral in the issuance of Real Estate Receivables Certificates (CRI) and use the proceeds for project financing.

The simplified structure of the SPE facilitates the formation of the CRI.

It's no coincidence that the use of the corporate structure of SPE has become so prevalent in sectors such as the construction industry. The benefits of risk reduction, decreased tax costs, and financial costs lead companies to seek the separation of ventures through this configuration to optimize business profitability. In addition to these advantages, there are some others:

- SPEs are typically used to isolate the financial risk of the activity being developed. Since it has legal personality, there is a greater commitment to achieving the objectives set by the parties involved. Thus, one no longer speaks of one company or another but rather of the SPE;
- Furthermore, with SPEs, there is the segregation of risks and an increase in management transparency. This is because it is simpler to verify the origin of resources;
- Moreover, there is the possibility of creating an SPE in the judicial recovery of companies, as credit and business opportunities appear dissociated from a specific crisis;
- It is also noteworthy that the temporal aspect is not characterized as a worrying point. There is the possibility of extending the duration of an SPE, as occurs in cases provided for in the fifth article of the PPP Law.

6.3.1.6 *Is there a reduction in risks, but do they persist?*

Yes. One important thing you need to know is that in this corporate model, as in many others, there will always be advantages and associated risks. Therefore, there are some precautions that need to be taken:

- Potential losses cannot be compensated with the shareholders' profits;
- Strong external control;
- Requires greater managerial, legal, and financial care, especially when carried out in conjunction with Public Entities..

6.3.1.7 *Legal Basis and Tax Aspects of Special Purpose Entities*

Before we delve into this subject, it is important to note that there is no specific law that deals with Special Purpose Entities (SPEs). And before the new Brazilian Civil Code (Law 10,406/2002), the legislation did not even expressly provide for SPEs as a type of commercial company. It was with the introduction of Article 981 in the Civil Code that the restriction of activities for the realization of one or more specific businesses was provided. As explained earlier, SPEs resemble a consortium or a joint venture.

In other words, two or more individuals and/or legal entities invest their skills and resources to execute specific and determined objectives. Once established, the Special Purpose Entity (SPE) acquires its own legal personality and consequently stands apart from the societies that formed it. By its nature, it has a highly restricted activity, and its existence and corporate purpose are limited to the activity it undertakes to perform.

6.3.2 Analysis of Advantages, Disadvantages, and Risks of SPE

Strategic partnerships in the formation of a Special Purpose Entity (SPE) are a common practice in public-private projects. Article 9 of the Public-Private Partnership Law (Law No. 11,079/04) makes it mandatory to establish an SPE to implement and manage the partnership's object. Thus, public and private partners associate themselves through an SPE, which is tasked with implementing and managing the venture.

From a legal standpoint, an SPE is a distinct and separate entity from the companies that comprise it. It is created for a specific purpose, with its own governance structure, responsibilities, and legal obligations. Shareholders or stakeholders participate in the SPE according to the terms of the founding contract, which defines their respective contributions, rights, and duties.

The formation of an SPE requires a founding contract that establishes the terms and conditions of the partnership among the participants. This contract typically contains information about the SPE's corporate purpose, duration, allocation of profits and losses, management of the company, among other relevant aspects. It is common for the contract to also provide mechanisms for resolving conflicts among shareholders or stakeholders.

The governance structure of an SPE may vary according to the project's needs and complexity. Generally, the SPE will have a board of directors or a board of shareholders/stakeholders responsible for making key strategic decisions. It is common for the parties involved to appoint an administrator or a specialized company to manage the SPE's daily operations.

SPEs offer several advantages to those involved in a specific project. They allow for the concentration of financial resources and specialized knowledge, reducing risks for participating companies. Additionally, SPEs can facilitate the obtaining of specific financing for the project, as creditors can evaluate the assets and revenues of the SPE separately.

However, SPEs also present challenges that must be considered. Coordination and decision-making among shareholders or stakeholders can be complex, especially in long- term projects. Moreover, it is essential that the founding contract of the SPE be well- drafted and comprehensively address the rights and obligations of the parties involved to avoid future conflicts and disputes.

Special Purpose Entities (SPEs) play a fundamental role in enabling complex and large-scale projects. Their legal nature and specific structuring allow participants to concentrate efforts and resources efficiently, mitigating the risks and responsibilities involved. However, it is important for stakeholders to seek specialized legal advice when establishing an SPE to ensure that all legal aspects are adequately addressed and protected.

6.3.3 Regulation of SPEs

Article 981 of the Civil Code of 2002 provided for the activities carried out by SPEs by stating that "the activity may be restricted to the performance of one or more specific businesses."

Furthermore, the Bankruptcy Law (Law No. 11,101/2005) mentions SPE in Article 50, item XVI, when dealing with judicial recovery, in the sense that it is possible to establish a special purpose society to adjudicate the debtor's assets in payment of debts.

In this manner, in these terms, the SPE resembles the American "joint venture" model, through which entrepreneurs combine financial, technological, and industrial resources to execute specific business objectives.

Additionally, as previously mentioned, the SPE can be formed as a limited liability company or a corporation, must comply with and meet all the requirements established in the legislation for each of these business models, with the difference that the company's corporate purpose must be limited to the achievement of one or more specific businesses or projects.

Moreover, as previously stated, Complementary Law No. 128/2008, which made several changes to Complementary Law No. 123/2006 (National Statute of Microenterprise and Small Business), sets out various conditions for its formation, especially in Article 56, as well as legal prohibitions that must be observed in this corporate model.

6.3.4 Main regulatory restrictions of Special Purpose Entities (SPEs)

Legislation imposes some restrictions on the adoption and operationalization of SPEs. Therefore, it is essential to consult the Company Registration Manuals.

For example, it is forbidden to transform any legal entity type into an SPE or vice versa.

Furthermore, as with other types of companies, the use of the acronym SPE in the formation of the corporate name is mandatory, a requirement that will be verified upon registration.

In addition, as restrictions on its constitution, we can cite the following:

- The SPE cannot be a branch, subsidiary, agency, or representation, in the country of a legal entity headquartered abroad;
- The SPE cannot be constituted in the form of cooperatives, including consumer cooperatives.
- The SPE cannot participate in the capital of another legal entity;
- The SPE is prohibited from engaging in the activities of commercial banking, investment and development banking, savings bank, credit, financing and investment company, real estate credit, brokerage or distribution of securities, securities and exchange broker, leasing company, private insurance, capitalization, or supplementary pension company;
- The SPE cannot be the result or residue of a split-up or any other form of dismemberment of a legal entity that has occurred in one of the five calendar years prior to its incorporation;
- The SPE cannot engage in any activity prohibited for microenterprises and small businesses opting for the Simples Nacional tax regime..

6.3.5 Procedures for the legalization of a Special Purpose Entity (SPE)

The first step is to register the articles of incorporation or bylaws of the SPE at the Commercial Registry corresponding to the jurisdiction of the established company, which must expressly state the purpose of the Company and its duration.

All obligations and duties of the SPE must be recorded in the accounts, and the company must begin issuing invoices and registering and declaring its operations according to applicable tax regulations.

The company's assets must also be composed and registered, defining the shareholders' responsibilities.

6.3.6 Considerations on the Proposal of an SPE for the Project

Our studies have taken into account the proposal of a Special Purpose Entity (SPE) for the development of the Total Project, considering the necessary investments for the construction and operation of the 45 Plants that will produce Biogas, including also the investments required for the construction and operation of the biorefineries that will produce Biomethane, green hydrogen, and Suncrude/SAF or Biomethanol.

The proposal presented and also analyzed by the legal support of the Project in question is considered viable with the three main participants of the presented economic model, namely the local Cooperatives in the region, and the companies MeLe and ENERTRAG. Both the Cooperatives and the solid participating companies have healthy financial conditions and will certainly constitute a viable and profitable SPE. The invested capital of approximately 30% among the three main investors is quite secure from a financial point of view, which places this composition of investors with adequate and enabled financial health and capacity to request and bear approximately 70% financing for the construction and operation of the productive units. The participation of German capital brings even more security to the financial operation in our understanding, being quite possible and probable the granting of financed capital.

Therefore, our opinion is highly favorable to the realization of this composition of investor actors in the projects, further emphasizing that the project inherently carries the support of public, private, and academic institutions that make the Project very important for regional, state, and national development towards Sustainability, and also reinforces the bonds of friendship between Brazil and Germany bringing mutual benefits in terms of environmental, economic, and social benefits to both countries, not to mention the benefits in local and global decarbonization.

6.4 Financing Opportunities for Biogas Projects

In addition to the technical nature and the strategic importance of diversifying the energy matrix, renewable energy sources also present positive impacts, which are aligned with the requirements and business opportunities associated with ESG (Environmental, Social, and Governance) programs, as well as may encompass some of the seventeen Sustainable Development Goals (SDGs) defined in 2016 by the United Nations (UN).

In this context, various banks and development institutions have created financing programs as a way to encourage the execution of projects and business models, considering the integrated positive impacts resulting from the implementation of renewable energy projects.

As an example of this initiative, we can mention the program created by the Government of the State of São Paulo, the "ESG - Sanitation and Waste Line," aimed at financing micro, small, and medium-sized enterprises for water preservation, basic sanitation, and solid waste treatment.

The "ESG - Sanitation and Waste" financing line, in addition to meeting SDG 6 - "Ensure availability and sustainable management of water and sanitation for all," is also aligned with SDGs 11 "Make cities and human settlements inclusive, safe, resilient, and sustainable" and 12 "Ensure sustainable consumption and production patterns."

Similarly, the Government of the State of Paraná, through Fomento Paraná, a state development financial institution, has been seeking investment for the region in the area of renewable energy, which includes solar panels, inverters, generators, wind energy such as small-scale wind turbines, and biomass energy generation systems.

Another important program created with the aim of combating climate change is the "Climate Fund Program," created by Law 12,114 on 09/12/2009, regulated by Decree 7,343 on 10/26/2010, and currently governed by Decree 10,143 on 11/28/2019.

The "*Climate Fund Program*" aims to "*support the implementation of projects, the acquisition of machinery and equipment, and technological development related to reducing greenhouse gas emissions and adaptation.*"*to climate change and its effects...*", comprising nine subprograms, including:

- Efficient Machinery and Equipment – aimed at the acquisition and production of machinery and equipment with higher energy efficiency rates or that contribute to the reduction of greenhouse gas emissions;
- Renewable Energies – focused on investments in activities aimed at the technological development of the solar energy, ocean energy, wind energy, and biomass sectors;
- Innovative Projects - support for innovative projects related to enterprises associated with the other subprograms of the Climate Fund Program;
- Carbon Management and Services - directed towards projects that improve carbon emissions management or effectively reduce greenhouse gas emissions.

The Low Carbon Agriculture Plan (ABC Plan), which aims to contribute to combating greenhouse gas emissions resulting from agricultural activities and making the sector's practices more sustainable.

Financing for the ABC Plan can be requested by rural producers (individuals or legal entities) and producer cooperatives (including for onward lending to members). This program includes, among others, projects related to the implementation, maintenance, and improvement of waste treatment systems and residues from animal production for energy generation and composting (ABC Waste Treatment).

6.4.1 Prerequisites for Obtaining Financing

For a project to be considered eligible for financing conditions, five fundamental points must be specified: (i) its technical feasibility, (ii) economic viability, (iii) availability of raw materials, (iv) demonstration that products resulting from its operation have a secured market, and (v) guarantees.

Expanding further on each of the presented items, we can consider the following aspects:

(i) Technical Feasibility – Project financiers must be convinced that all processes, technology, and equipment to be used can indeed produce and generate revenues according to the projected capacity. Generally, to increase the project's credibility with financiers, letters from equipment manufacturers or third-party technical certificates are presented, proving both the manufacturers' experience and the operational capacity of the equipment.

(ii) Economic Viability – The project must demonstrate the ability to generate cash flow associated with its operation, clearly showing that the generated revenues can cover debt costs and, at the same time, ensure an attractive return rate to investors/financiers. Additionally, the project's structure must be robust enough to continue generating cash flow even in adverse scenarios, such as delays during the construction stage or delays in project implementation or operation commencement

(iii) Availability of Raw Materials – It must be demonstrated that there are sufficient natural resources (e.g., water and electricity) to ensure the project's operation during the period for which its cash flow was projected. This requires contracts to be defined with all project suppliers, specifying all necessary conditions to ensure the supply of raw materials.

(iv) Market Definition – It must also be demonstrated that the products generated by the project, such as methanol, syncrude, etc. (to be confirmed), have available buyers and that the market pricing considered in the project analysis reflects real market conditions. An example of such commitment can be presented based on energy generation projects, many of which already have purchase and sale contracts with defined values.

(v) Guarantees – It is often required that the project developer provide guarantees capable of covering, generally, from the construction phase to the implementation and compliance with operational indicators ensuring the project's proper operation.

6.4.2 Risks and Mitigation Measures

Many of the aforementioned conditions and other requirements for obtaining financing can be identified through a risk analysis. Table 9 presents some risks to be considered in the project development and their respective mitigation measures.

Table 6-9 Risks and Mitigation Measures in Projects to be Presented for Financing

Risks	Mitigation
Associated with CAPEX	• Pre-development of basic and/or engineering executive project; • Validation of budget and technical aspects by third-party independent or similar entities; • EPCM (Engineering, Procurement, and Construction Management) construction contract, where the contractor is responsible for project management and administration. • If applicable, implementation of performance insurance.
Associated with OPEX	• Develop an O&M contract and require a demonstration of equipment operation capacity; • Simulate the effect of operational cost increases in contracts to assess the impact of such increases on debt costs; • Evaluate the technical operation requirements and knowledge of equipment maintenance personnel.
Associated with demand	• Assess the market and potential forms of commercialization of the project's generated products (to be defined); • Identify possible risks and factors affecting the supply- demand relationship of the products and their impacts based on the project's production capacity. • If possible, establish long-term purchase contracts.
Associated with Financing	• Analyze the developers' capacity to invest their own resources in the project; • Provide guarantees not only for own resources but also covering any additional costs during the project implementation phase and, if applicable, also during the operation phase..
Regulatory and Political	• Evaluate how variations in interest rates and other macroeconomic parameters can affect financing costs among financing possibilities. • Specific regulations regarding biofuel production, considering both national and international legislation, in cases where project-derived products are exported.
Socio-environmental	• Conduct an assessment of the environmental impacts resulting from the project implementation. • Verify the necessary conditions for obtaining environmental licenses. • Conduct environmental impact studies.

	• Implement necessary monitoring actions to ensure that the project operates safely and does not negatively affect surrounding communities.
Force Majeure	• If applicable, seek insurance contracts to minimize financing costs by reducing premiums for project operation risk.

6.4.3 Project Implementation Phases

Observing Table 7.2, it is possible to verify that risks are inherent in each stage of project execution. Essentially, two stages can be considered for project development: the pre-operational stage, also referred to as "pre-completion", and the operational stage, or "post-completion.".

6.4.3.1 Pre-operational Stage, also known as "pre-completion"

The pre-operational phase corresponds to the physical and financial implementation of the project and requires the following steps to have been already addressed:

(i) obtaining environmental permits,
(ii) defining the project's financing structure, considering both own and third-party investments,
(iii) defining the participation forms of each project stakeholder, considering legal models.

During this stage, the most significant risks for project implementation occur, with major impacts on its cash flow, such as delays in equipment delivery and civil construction works, directly affecting the project's operational start and revenue generation. Such impacts can significantly affect the pre-agreed financing costs between investors and project developers. The pre-operational phase is completed with the physical implementation of the project and assessing whether the technical-operational performance indicators have been achieved. Specifically, it is verified whether the operational equipment, control systems, and monitoring systems are properly installed and perform as expected.

6.4.3.2 Operational Stage, or "post-completion"

This phase is characterized by the commercial operation start of the project, verifying and monitoring equipment performance and revenue generation. A negotiable characteristic at this stage is the grace period for payment for several months after the project's operational start, given that in the initial operation phase, the project may not generate sufficient revenue to achieve economic and financial performance.

During this stage, it is essential to monitor the project's operating costs (OPEX), verifying if they are in line with the initial projections, and if necessary, taking measures to adjust costs to maintain the required efficiency to meet the projected revenues. Generally, when operational costs exceed the initial forecast, it will be up to the project developers to bear this investment, highlighting the importance of adequate planning to avoid jeopardizing the project's ability to meet its goals.

6.4.3.3 Debt Amount and Risk Assessment

To provide credit, financing agents require demonstration that the projected values for operational cash generation (EBITDA discounted from working capital) are more than sufficient to cover debt service costs (interest + amortization), ensuring liquidity to address long-term financing risks. For this purpose, the Debt Service Coverage Ratio (DSCR) is the main indicator to evaluate the project's feasibility, calculated according to equation 1.

- ICSD = Operating cash generation/debt service (GOC) (equation 1), where:
  GOC = EBITDA - Taxes -/+ Working capital variation.

Financing sources usually require that the projected DSCR values be greater than or equal to a pre-established minimum value throughout the financing term, in all periods in which the indicator is calculated, to grant the loan. Regulatory bodies of the capital market and the financial system determine that institutions classify credit operations in ascending order of risk, in this case, risks correspond to the expectations of losses that may occur to a project lender. The main factors used by these agencies consider, among others, the following factors:

- Long-term commercial viability and competitive position – analyze the service provided or the introduction of a product in the market in terms of cost, location, technological development, alignment between project stakeholders' interests, among others.
- Cash flow stability – analyze the project's exposure to demand risks and unforeseen variations in construction and operation stages.
- Financial metrics – consider how lenders are protected in project structuring, availability of reserve accounts for O&M debts, asset disposition.

6.4.3.4 Corporate Structures

Although corporate structures are defined throughout the project, the approach to this topic at this stage is only aimed at directing possible structures that can be defined among all project participants.

Based on Project Finance structures, a commonly used structure consists of the contribution of equity by the requirements of creditors, as a way to create guarantees and demonstrate the reliability of developers with the project.

Another modality consists of creating Special Purpose Entities (SPEs), which delimit the object of the venture, isolating the risk/return relationship from other activities of those involved in the project and allowing greater transparency of the operations.

SPEs can be constituted as Open Capital (OC) or Limited Liability Companies (Ltd.).

In OC, each shareholder is responsible, in case of insolvency of the company, for the value of the subscribed but unpaid-up share capital. Ltd. are, in case of insolvency of the company, jointly responsible up to the limit of the share capital to be paid up. These aspects should be considered when corporate models are evaluated in this work.

6.4.3.5 Project Presentation Model for Financing Agents

This section proposes a model for presenting the project to investment funds and financing agents, presenting the following items:

- Project objective
- Project description: location, risk assessment
- Basic project characteristics: equipment, equipment supply contracts, others
- Involved parties, roles, and responsibilities
- Intended capital structure
- Risk x Mitigation matrix
- Obtained guarantees

6.4.3.6 Evaluation of Financing Lines

The Evaluation of Financing Lines is a fundamental practice for financial institutions, governments, and companies seeking to understand and optimize the impact of their credit and investment programs. This process involves the rigorous analysis of a series of factors, including the cost-benefit of the financing lines, associated risk, suitability to strategic objectives, and financial viability of the proposals. The ultimate goal of the evaluation is to ensure that the financing lines are well-conceived, meet market needs, and contribute to sustainable economic development. For evaluation, some key points are essential:

6.4.3.7 Project Objectives Definition

- Clearly identify the project's financial objectives.
- Establish financing needs, deadlines, and the required amount.

6.4.3.8 Identification of Financial Institutions

- Research and list financial institutions that offer financing lines suitable for your Project
- Consider banks, development agencies, and other financial entities.

6.4.3.9 Information Gathering

- Obtain specific details about each financing line, including interest rates, terms, monetary adjustments, correction indexes, required guarantees, among others.

6.4.3.10 Analysis of Interest Rates

- Compare the interest rates offered by each institution.
- Evaluate whether the rates are fixed or variable and consider the impact on costs over time.

6.4.3.11 Monetary Adjustments and Correction Indexes

- Understand the methodologies of monetary adjustment and the indexes used by each institution.
- Consider the stability and predictability of these indexes for better financial planning.

6.4.3.12 Costs and Additional Charges

- Analyze possible additional costs, such as credit opening fees, mandatory insurance, and other charges.
- Include these costs in the overall assessment of financing.

6.4.3.13 Terms and Grace Periods

- Evaluate payment terms and possible grace periods.
- Consider the flexibility offered by the institution regarding terms.

6.4.3.14 Required Guarantees

- Verify the guarantees requested by each institution.
- Evaluate the feasibility of providing the required guarantees.

6.4.3.15 *Contractual Flexibility*

- Consider the flexibility offered by the institutions regarding contractual adjustments and renegotiations.

6.4.3.16 *Risk Analysis*

- Assess the risks associated with each financing line, including market risks, credit risks, and other relevant factors.

6.4.3.17 *Financial Simulations*

- Perform financial simulations for each financing option, considering different economic scenarios.
- Evaluate the impact of financial variables over time.

6.4.3.18 *Decision and Negotiation*

- Make a decision based on the analysis conducted.
- Be prepared to negotiate the terms of financing, if possible.

6.4.3.19 *Specific Financing Lines*

The specific lines for obtaining financing for the implementation of renewable energy projects are presented in the following tables. These are lines made available by the main Development Agencies (National, Regional, and State). Some of the objectives described in the funding sources, although not directly related to renewable energy generation projects, can be accommodated when considering the other benefits generated as a result of project implementation.

Main Development Agencies (National, Regional, and State), Banks, and Funds:

- AFAP – Agência de Fomento do Estado do Amapá S/A – https://www.afap.ap.gov.br/
- AFEAM – Agência de Fomento do Estado do Amazonas S/A – https://www.afeam.am.gov.br/
- AGE – Agência de Empreendedorismo de Pernambuco – http://www.age.pe.gov.br/
- Agência de Fomento de Goiás S/A – https://www.goiasfomento.com/
- AGERIO – Agência de Fomento do Rio de Janeiro – https://www.agerio.com.br/
- AGN – Agência de Fomento do Rio Grande do Norte S/A – http://www.agn.rn.gov.br/
- BADESC – Agência de Fomento do Estado de Santa Catarina – https://www.badesc.gov.br/portal/
- BADESUL – Agência de Fomento do Rio Grande do Sul – https://www.badesul.com.br/
- Banco BV – https://www.bv.com.br/para-empresas/emprestimos-e-financiamentos
- BANDES – Banco de Desenvolvimento do Espírito Santo – https://www.bandes.com.br/
- BASA – Banco da Amazônia – https://www.bancoamazonia.com.br/
- BB – Banco do Brasil – https://www.bb.com.br/site/pra-voce/financiamentos/
- BDMG – Banco de Desenvolvimento de Minas Gerais – https://www.bdmg.mg.gov.br/
- BNB – Banco do Nordeste Brasileiro – https://www.bnb.gov.br/
- BNDES – Banco Nacional de Desenvolvimento Econômico e Social – https://www.bndes.gov.br/
- BRDE – Banco Regional de Desenvolvimento do Extremo Sul – https://www.brde.com.br/
- Desenbahia – Agência de Fomento da Bahia S/A – https://www.desenbahia.ba.gov.br/
- Desenvolve Alagoas – Agência de Fomento de Alagoas – https://www.desenvolve-al.com.br/
- Desenvolve MT – Agência de Fomento de Mato Grosso – https://www.desenvolve.mt.gov.br/
- Desenvolve Roraima – Agência de Fomento do Estado de Roraima – https://desenvolve.rr.gov.br/
- Desenvolve SP – Agência de Fomento de São Paulo – https://www.desenvolvesp.com.br/

- FG/A Gestora de Recursos Ltda - Fundo Garantidor de Biogás – https://fga.com.br/blog/all/biogás/1/
- Fomento Paraná – Agência de Fomento do Paraná – https://www.fomento.pr.gov.br/
- Fomento Tocantins – Agência de Fomento do Estado de Tocantins – https://www.fomento.to.gov.br/
- Piauí Fomento – Agência de Fomento e Desenvolvimento do Piauí S/A – https://portal.pi.gov.br/fomento/

ATTENTION: The Financing Programs spreadsheet is being reviewed and updated to ensure the accuracy of the provided information. It includes details on interest rates, terms, and grace periods applicable to each financing program, along with eligible items and specific objectives associated with each. The comprehensive checklist in this spreadsheet encompasses essential information for a thorough and accurate assessment of available financing options in the Brazilian market, providing updated and reliable data to support informed decision-making.

Table 6-10 Financing Lines

Funding Fund	Limit	Objectives	Characteristics	Eligible Financing Items
BADESC | BADESC FOMENTO	From R$ 250,000 to R$ 5 Million	The credit line aims to support investment projects in the industrial, commercial, and service sectors, targeting businesses of various sizes within the private sector.	The maximum working capital leverage limit will be 30% (thirty percent) of the fixed investment portion. For fixed investment and mixed capital operations, an investment project will be required, except for single-item financing. The credit line allows for financing starting from a minimum of R$250,000.00 up to a maximum of R$5,000,000.00. The grace period and total financing term will be determined based on the company's or institution's repayment capacity, subject to the following maximum limits: a)Grace period: up to 18 (eighteen) months; b)Total term (grace period and amortization): up to 96 (ninety-six) months.	Fixed assets, both new and used: - Machinery and Equipment - Utility Vehicles - Industrial Systems - Consultancy and modernization systems - Construction and installations - Investments made up to 12 months prior - Organizational restructuring - Technological Development - Franchise investments - Migration from AM to FM band (radio stations)
BANCO NORDESTE | FNE INOVAÇÃO	Not Applicable (N/A)	Supports investment projects in innovation in non-rural sectors: projects aimed at implementation, expansion, modernization,	Investment Amount Location Factor Annual % Monthly % Up to R$ 200,000 Priority Typology IPCA* + 0.9127% IPCA* + 0.075742% Non-Priority Typology IPCA* + 1.1156% IPCA* + 0.092494% Above R$ 200,000 Priority Typology IPCA* + 1.6429% IPCA* + 0.135888%	- Scholarships - Construction Costs - R&D Expenses - Travel Expenses - Labor Costs - Raw Materials - Consumables - Third-Party Services - Software

		or renovation that enable innovations in products, services, processes, and organizational methods within enterprises, including the preparation of environmental studies.	Non-Priority Typology IPCA* + 2.008% IPCA* + 0.165812%	
BANCO NORDESTE | FNE VERDE	N/A	Promover o desenvolvimento de empreendimentos e atividades econômicas que propiciem a preservação, conservação, controle e/ou recuperação do meio ambiente, com foco na sustentabilidade e competitividade das empresas e cadeias produtivas.	Mixed investment refers to investments with associated working capital, receiving the same treatment regarding the term of the working capital.	Implementation, expansion, modernization, and renovation of enterprises Sustainable use of forest resources Environmental recovery and coexistence with semi-arid regions Agroecological production, organic farming or livestock systems, and agroecological transition Renewable energies and energy efficiency Environmental planning and management
BANDES | INOVAÇÃO	N/A	The credit line aims to support companies in Espírito Santo in the production and introduction of innovative products and/or services to the market; acquisition of these products or services by third parties; and the implementation	Legal entities located in Espírito Santo that meet at least one of the following conditions*: a) Are incubated/accelerated or have been graduated/accelerated in the state; b) Have been supported by a call from the Foundation for Research Support of the State of Espírito Santo (FAPES) and/or the Financier of Studies and Projects (FINEP), as well as other municipal, state, or federal agencies;	Investment in infrastructure Associated working capital, limited to 30% of the total investment amount Exclusive working capital for pioneering production Expenses related to patent filing and maintenance in Brazil and abroad Expenses for market introduction of innovations, limited to 30% of the total investment amount Investment project development, limited to 2% of the total investment Acquisition of land linked to the project, located in

		or relocation of innovative companies.	c) Have patented a product and have a project to reproduce this product and/or process; d) Technology-based companies (1); e) Companies belonging to knowledge-intensive sectors.	innovation environments/technological parks
BDMG | BDMG SUSTENTABILIDADE	N/A	Facilitate long-term projects focused on energy generation for medium and large companies. • Photovoltaic energy projects • Small Hydroelectric Power Plants (SHP) • Hydroelectric Power Plants (HPP) • Sustainable public lighting projects • Energy efficiency projects	Grace period: up to 24 months Total term: up to 144 months Financing intended for renewable energy and energy efficiency projects, civil works, installations, services, equipment, photovoltaic generator components and systems for companies with annual revenue exceeding R$ 16 million. Interest rate starting from SELIC + 3.09% per year and APR (Annual Percentage Rate) starting from SELIC + 3.54% per year. Product subject to Corporate IOF (Tax on Financial Transactions) of 0.0041% per day (limited to 1.5% per year + additional 0.38%). Financing limited to 75% of project value, subject to credit analysis and resource availability, with investments requiring proper verification and adherence to guidelines and recommendations of BDMG CLIMATE ACTION FL II - Finance Contract No. 90,645.	Unrestricted
BNDES | BNDES CRÉDITO ASG	R$ 150 Million	Direct support through Environmental, Social, and Governance (ESG) credit for business plans, with a focus on sustainable development. • Promoting reforestation, supporting the	Financing ranging from R$ 20 million to R$ 150 million for investments in ESG, through direct application to BNDES. Interest rate = Financial Cost Factor (TLP, TS, or Fixed Rate) + BNDES Compensation + Credit Risk Rate BNDES Compensation: 1.5% per annum Credit Risk Rate: Variable according to client risk and financing term.	Unrestricted

		timber chain, and ecotourism; • Stimulating sustainable technologies in the Mining, Metallurgy, and Steel sectors; • Increasing the use of clean energy; or • Expanding the connectivity offerings of regional Internet providers..	Term: Limited to 96 months, with a grace period of up to 24 months	
BNDES | BNDES FINEM INOVAÇÃO	Starting from R$ 10 Million	Innovation Investment Plan encompassing both company capacity building for innovation and potentially disruptive or incremental innovations in product, process, and marketing.	Support Conditions: Financing starting from R$ 10 million for investments in innovation, through direct application to BNDES. Interest rate = Financial Cost Factor (TLP[1]) + BNDES Compensation + Credit Risk Rate BNDES Compensation: 0.9% Credit Risk Rate: Variable according to client risk and financing term. In indirect operations, the interest rate is composed of the Financial Cost, the BNDES Rate (1.05%), and the Financial Agent Rate (negotiated between the institution and the client) Term: Limited to 20 years	Scholarships Working Capital Civil Construction R&D Expenses Pre-operational Expenses Travel Expenses Labor Costs Raw Materials Machinery and Equipment Consumables Furniture Third-Party Services Training, Studies, and Projects
BNDES | FINEM – CRÉDITO INOVAÇÃO DIRETO	R$ 20 Million	Financing for investments in innovation for companies of all sizes.	Support conditions: Financing starting from R$ 20 million for investments in innovation, through direct application to BNDES. Interest rate = Financial Cost Factor (TLP) + BNDES Compensation + Credit Risk Rate BNDES Compensation: 0.9% Credit Risk Rate: Variable according to client risk and financing term.	Studies, projects, R&D research Tests, trials, and certifications both domestically and internationally Civil works, assemblies, and installations Acquisition of consumable and permanent materials Direct labor costs New domestic machinery and equipment accredited by BNDES

			In indirect operations, the interest rate is composed of the Financial Cost, the BNDES Rate (1.05%), and the Financial Agent Rate (negotiated between the institution and the client) Term: Limited to 20 years	Domestic or imported software, if no domestic equivalent is available Current R&D expenses Scale-up of processes and parameter adjustments Factory investments
BNDES | FINEM - INVESTIMENTOS SOCIAIS	Minimum financing amount: R$ 40 Million	Financing for social projects and programs to be carried out by companies, associations, and foundations of all sizes	Community Scope: 1. Actions targeting populations exposed to some form of social risk and located in communities within the influence areas. 2. Actions benefiting local suppliers of ancillary goods and services (industrial clothing, gifts, food, security, minor repairs, transportation, among others) with direct impact on social inclusion in that community. Company Scope: 1. Implement or enhance environmental, social, and/or occupational health and safety management systems. 2. Obtain certifications, both for the client and for companies in its supply and distribution chain. 3. Facilitate social investments, supplementary to legal obligations, aimed at the company's employees as well as employees of companies in its supply and distribution chain.	N/A
DESENVOLVE SP | LINHA ECONOMIA VERDE	N/A	Promote projects that foster the reduction of greenhouse gas emissions, renewable energy generation, and energy efficiency. Through sustainable practices that minimize the impact of	Support Conditions: • Interest Rate: Starting from 0.53% per month plus SELIC • Term: Up to 120 months* • Grace Period: Up to 24 months • Financing up to 80% of the value of eligible items *Including the grace period	Agribusiness Fuel change Sanitation, waste treatment, and utilization Energy efficiency Transportation Industrial processes Forest restoration in urban and rural areas Waste management Construction industry

		production activities on the environment, such as reducing energy consumption, switching from fossil fuels to renewables, or investing in reforestation and preservation of natural resources.		
DESENVOLVE SP | LINHA INCENTIVO À TECNOLOGIA	up to R$ 30 Million	Funds projects up to R$30 million for the development and transfer of technology, creation of new products, processes, or services, investments in infrastructure, research and development, which incorporate technological advancements or innovative processes for small and medium-sized enterprises	Support Conditions: Interest Rate: Starting from 0.33% per month plus SELIC Term: Up to 120 months including grace period Grace Period: Up to 24 months Participation: Up to 90% of the value of eligible items *Facilitated guarantee for small/medium enterprises	Expenses for IP (Intellectual Property) Machinery and Equipment Inputs/Materials Third-Party Services Training and Development Software
FINEP | FINEP CONECTA	Starting from R$ 5 Million	Supporting investments linked to companies' innovation strategies across all sectors of the economy.	Action Line Fee Bonus Grace Period Total Term Conecta 15 1% reduction in the rate Identical to the action line in which the project is classified Identical to the action line in which the project is classified. Conecta 25 1% reduction in the rate Up to 60 months Up to 144 months	All related to R&D, including imported equipment. Does not support working capital or purchase of land or real estate.

			Conecta 50 1% reduction in the rate Up to 60 months Up to 192 months	
FINEP APOIO DIRETO À INOVAÇÃO	Starting from R$ 10 Million	Supporting investments linked to companies' innovation strategies across all sectors of the economy.	A. Interest rate based on TJLP*, ranging from TJLP- 2%*** to TJLP+6.25% per year, depending on the line and bonuses (rate reducers). B. Specifically for projects in the Telecommunications sector, interest rate based on TR*, ranging from TR+5%*** to TR+7% per year. Grace period: 24 to 48 months Total term: up to 12 years * TJLP = 4.61% per year; value for Jan/2021 to Mar/2021 ** TR = 0.00% per year; *** Considering guarantee bonus and FINEP Conecta or FINEP Educação or FINEP IoT bonus.	Internal R&D External acquisition of R&D Acquisition of other external knowledge Software acquisition Training Introduction of technological innovations into the market Acquisition of machinery and equipment Pioneering production and other preparations for production and distribution Mergers and acquisitions All related to R&D&I, including in foreign currency Acquisition of startups or companies for technology absorption Does not support working capital or purchase of land or real estate.
FINEP| FINEP SUSTENTABILIDADE	N/A	The objective is to support the development and adoption of technologies for reducing the consumption of natural resources. Strategic Innovation Plans for the development and/or adoption of technologies aimed at reducing natural resource consumption are eligible for support, aligned with one of the	Action Line Fine Tuning Rate Critical Innovation TJLP – 1.488% p.a. Up to 100% Pioneering Innovation TJLP – 0.424% p.a. Competitiveness Innovation TJLP + 0.640% p.a. Performance Innovation TJLP + 2.768% p.a. Technological Diffusion for Innovation Selic + 5.3% p.a.	Internal R&D Expenses External R&D Acquisition Acquisition of other external knowledge Software Acquisition Training Introduction of Technological Innovations in the Market Acquisition of Machinery and Equipment Pioneering production Other preparations for production and distribution Fusion and acquisition

		following themes: - Reduction of natural resource use directly in the production process, notably water; - Utilization of waste under the concept of circular economy to decrease natural resource consumption; - Agricultural and industrial water reuse; - Reduction of losses in urban and rural water supply systems; - Efficiency and rational use of water in production processes, including irrigation; - Technological solutions that enhance rational water use and access to water and sanitation.

6.5 Interviews – Financial / Development Institutions

To ensure a comprehensive and accurate evaluation of financing options, a survey of respective collaborators is being conducted with the aim of scheduling meetings with experts from the responsible institutions. These meetings will serve as an opportunity to clarify doubts, obtain more information, and discuss specific details about each financing option. To facilitate the scheduling of these meetings, a table with the contacts of responsible individuals from each institution is being organized. This approach aims to ensure that all stakeholders have access to detailed and updated information, promoting a thorough and well-informed analysis of available financing options.

Table 6-11 Survey of contacts in Financial Institutions / Development Agencies

Contacts	Position / Institution	Professional Profile
Alexandre Siciliano Esposito	Head of Department | Energy | BNDES	https://www.linkedin.com/in/alexandre-siciliano/
Pedro Protasio	Project Structuring at BNDES	https://www.linkedin.com/in/pedro-protasio-8a0537124/
Geanderson Souza	Gerente at BNDES	https://www.linkedin.com/in/geanderson-souza-7bb6b426/
Marcelo Melo	Financing Manager | BNDES	https://www.linkedin.com/in/marcelo-melo-522a4114/
Mauricio Bernhardt	Project Finance Analyst | BNDES	https://www.linkedin.com/in/mauricio-bernhardt-171155216/
Newton Hamatsu	Superintendent of the Innovation Area at FINEP - Financiadora de Estudos e Projetos.	https://www.linkedin.com/in/newton-hamatsu-44452431/
Henrique Leite de Vasconcellos	Manager of Corporate Sustainability at Banco do Brasil S/A	https://www.linkedin.com/in/henrique-leite-de-vasconcellos-3a8421173/
Guilherme Arantes	Sector Manager for Electric Power | BNDES	https://www.linkedin.com/in/guilherme-arantes-419a991/

6.6 Cash Flow and Financial Modelling Results

Within this Project, we directed our efforts towards understanding and comprehensively gathering all relevant data regarding capital costs (Capex), operational and maintenance costs (Opex), and revenue estimates from the 45 biogas production plants and Biorefineries dedicated to the production of biofuels from biogas and green hydrogen, namely Syncrude/SAF and Biomethanol. In this context, we dedicated ourselves to developing a financial model with specialized spreadsheets aimed at supporting detailed analysis of cash flows associated with this endeavor. These meticulously crafted tools allow for a clear and precise visualization of the crucial financial elements necessary for strategic decision-making, thereby contributing to the effectiveness and success of the project at hand.

Initially, we focused our efforts on the detailed understanding of the key parameters of the 45 biogas production plants, as well as the respective biorefineries intended for Syncrude/SAF and Biomethanol production. This initial approach aimed to ensure a comprehensive and in-depth understanding of the operational and financial context of these facilities, providing a solid foundation for the subsequent analysis of cash flows associated with these ventures.

In the subsequent stage, efforts were concentrated on developing a Sensitivity Analysis Spreadsheet, aimed at evaluating various possible scenarios. This tool will utilize consolidated data to compare the effects of variations in the Internal Rate of Return (IRR) for different financing options. This approach will allow for a thorough analysis of the risks and opportunities associated with the project, providing valuable insights for strategic decision-making.
It is essential to emphasize that, for the economic and financial analysis, we are identifying the key elements that will influence the cash flow. This includes special attention to detailing all relevant factors for constructing the cash flow spreadsheet, enabling a clear visualization of all items that will have a direct impact on the project's financial flow.

For an assessment of the scenarios, we performed cash flow analysis using data from the 45 biogas production plants, in order to analyze the profile of the Net Present Value (NPV) curve and the respective investment payback period, as well as the Internal Rate of Return (IRR). In the later stages of the studies, we incorporated into this analysis all detailed elements, including the economic parameters of the biorefineries, and subsequently, the specific project elements, mainly utilizing the data reported in Technical Report 3, prepared by experts, on the employed Technologies, from UFPR - Federal University of Paraná with technical support from NIRAS.

Several scenarios were considered in the studies, and as we progressed, the information was shared with our contractors and supported by local and foreign professionals, culminating in the final scenarios presented below. The scenarios considered were as follows:

- Syncrude: Scenarios A and B
- Biometanol: Scenarios C1-C4

Next, we present the result obtained from the analysis of the Scenario for the implementation of the 45 considered plants for the construction of the biogas production facility.

- CAPEX: € 548.048.584,20
- OPEX: € 114.512.048,55
- Revenue (estimates): € 196,115,993.24
- Operating Period: 20 years
- Payback Period: 10 years

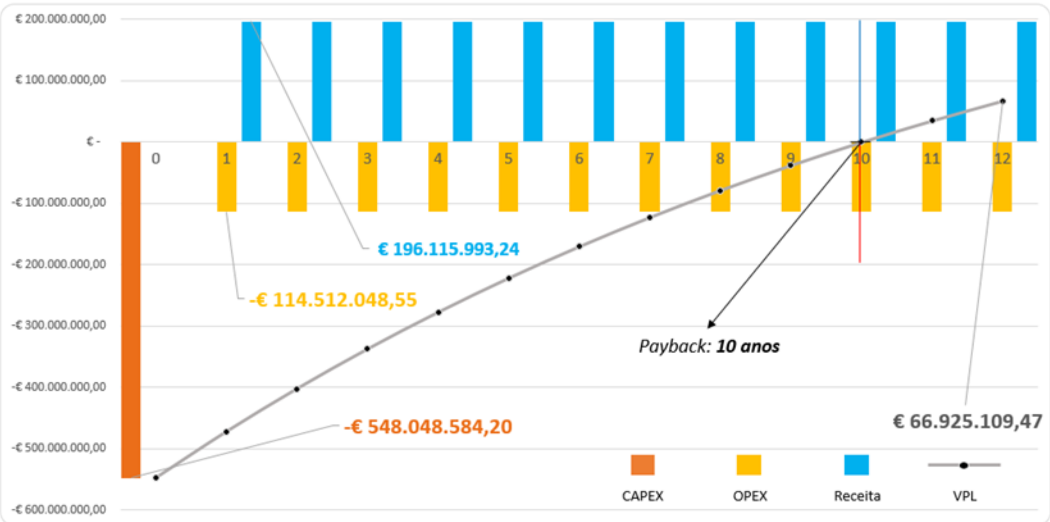

Figure 6-5 Cash Flow for the implementation of the 45 biogas plants

Following, we present the results obtained from the analyses of the construction projects of the biorefineries, firstly for the alternatives considered in the scenarios for the production of Syncrude/SAF. For this analysis, as mentioned earlier, the alternatives of Scenarios A and B were considered.

6.6.1 Syncrude: Scenario A

As a result, Scenario A proved to be more economically attractive than Scenario B; however, due to technological reasons, Scenario A was discarded as it presented technological barriers that rendered the construction of the Biorefinery unfeasible.

Table 6-12 Technical, economic and financial parameters of scenario A

SYNCRUDE	Obs.	Scenario A
CAPEX Total	TCI (modules, engineering, BoP, civil and contingency) (Millions €)	€ 714
OPEX Total	(plant operations, utilities maintenance, depreciation and interests) (Millions €)	€ 217
Production	(Ton/h)	15.42
Numbers of Hours	(h)	8,117
Production	(Ton / year)	125,164
Euro / Ton		€ 2,000.00
Annual Revenue (A)	(Millions €)	€ 250.33
Biogas Plant		MM€ 530 / 15 anos
Annual installment (B)	(Millions €)	€ 35.33
(A)+(B)		
Year 2 to Year 16	(Millions €)	€ 285.7
Year 17 to Year 20	(Millions €)	€ 250.3
Capital Sources		
Equity (E)	30.0%	€ 214.2
Third Party Capital (D)	70.0%	€ 499.7
Income tax (zero % due to applied incentives)	34.0%	-

Inflation	2.0%	-
Cost of internally sourced capital (Ke)	10%	-
Cost of capital from external sources (Kd) (50% development bank + 50% private bank)	6%	-
WACC	$WACC = [Ke\left(\frac{E}{D+E}\right) + Kd\left(\frac{D}{D+E}\right)]*(1\text{-}T)$	4.8%

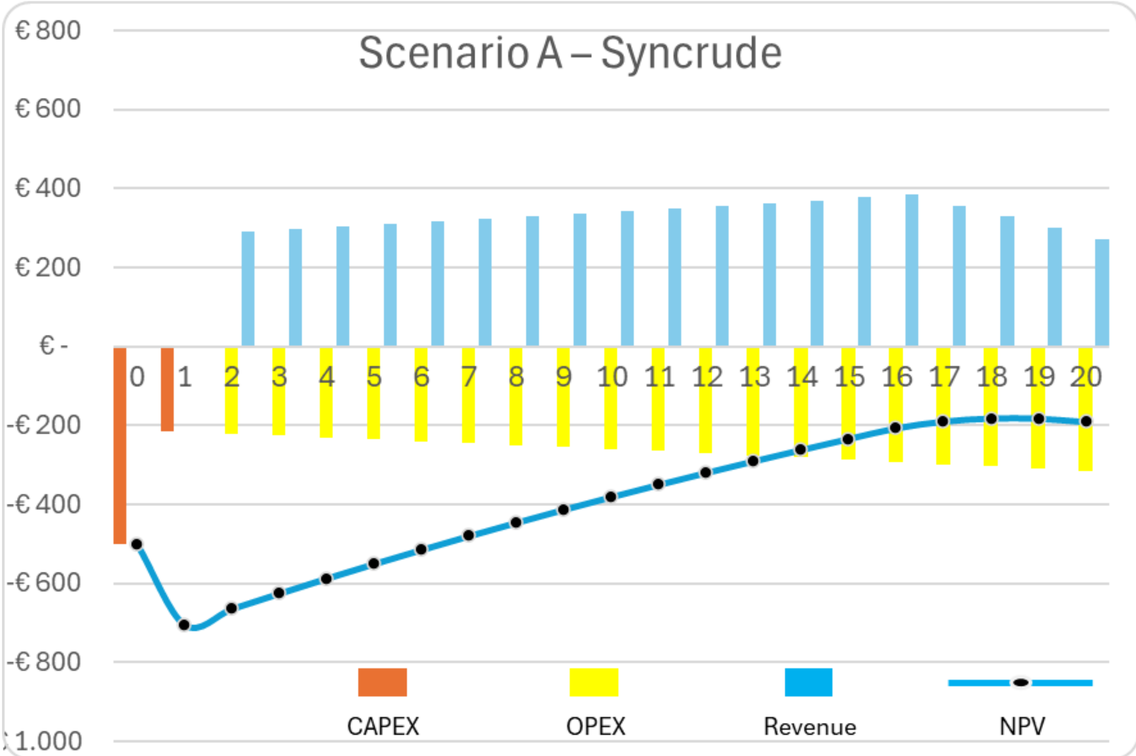

Figure 6-6 Cash Flow of Scenario A – Syncrude

Table 6-13 Analysis of the viability of Scenario A

SYNCRUDE Cenário A	
Net Present Value (NPV) (Millions €)	-€ 191
Internal Rate of Return (IRR) (%)	negativa
Payback (years)	inviável

6.6.2 Syncrude: Scenario B

As for Scenario B, it proves to be viable from a technological standpoint; however, economically it appears unfeasible due to the high investment and market price not being compatible with the required investment, resulting in a negative NPV and many years for the return, indicating a significantly long payback period. In this case, the Levelized Price is well above the market price, rendering the investment unviable.

Table 6-14 Technical, economic and financial parameters of scenario B

SYNCRUDE	Obs.	Scenario B
CAPEX Total	TCI (modules, engineering, BoP, civil and contingency) (Millions €)	€ 1,601
OPEX Total	(plant operations, utilities maintenance, depreciation and interests) (Millions €)	€ 385
Production	(Ton/h)	21.80
Numbers of Hours	(h)	8,117
Production	(Ton / year)	176,967
Euro / Ton		€ 2,000.00
Annual Revenue (A)	(Millions €)	€ 353.93
Biogas Plant		MM€ 530 / 15 anos
Annual installment (B)	(Millions €)	€ 35.33
(A)+(B)		
Year 2 to Year 16	(Millions €)	€ 389.3
Year 17 to Year 20	(Millions €)	€ 353.9
Capital Sources		
Equity (E)	30.0%	€ 480.2
Third Party Capital (D)	70.0%	€ 1,120.6
Income tax (zero % due to applied incentives)	34.0%	-
Inflation	2.0%	-
Cost of internally sourced capital (Ke)	10%	-
Cost of capital from external sources (Kd)	6%	-

(50% development bank + 50% private bank)		
WACC	$WACC = [Ke\left(\frac{E}{D+E}\right) + Kd\left(\frac{D}{D+E}\right)]*(1\text{-}T)$	4.8%

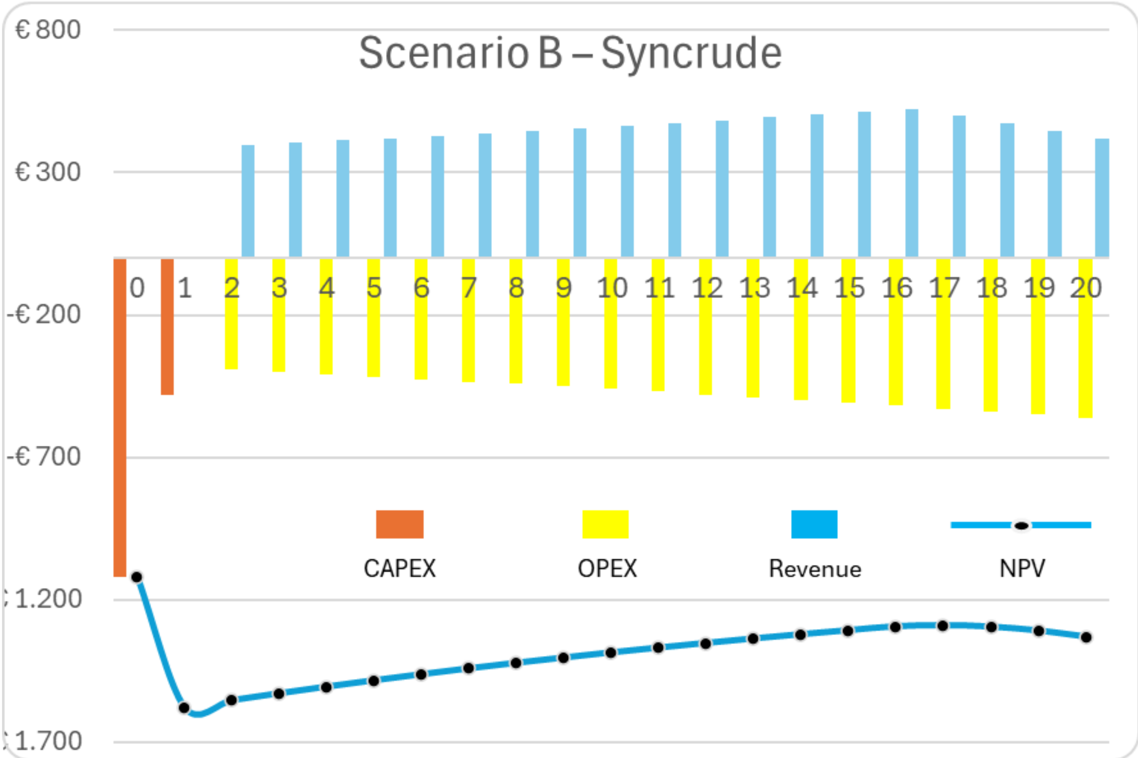

Figure 6-7 Cash Flow of Scenario B – Syncrude

Table 6-15 Analysis of the viability of Scenario B

SYNCRUDE Cenário B	
Net Present Value (NPV) (Millions €)	-€ 1,331
Internal Rate of Return (IRR) (%)	negativa
Payback (years)	inviável

6.6.3 Biometanol: Scenario C

In the context of the analysis for bio-methanol production (Scenario C), four new scenarios based on different sets of input data were examined, designated respectively by the data sources: NIRAS, MeLe, Uncertainty 50% and NIRAS latest improved financial analysis.

In the scenario with input data provided by NIRAS, we analyzed the CAPEX data as provided in NIRAS company studies. In the MeLe scenario, we used input data provided by MeLe company for our analysis. In the Uncertainty 50% scenario, we considered a 50% reduction in investment values, as NIRAS and MeLe studies may have an uncertainty of approximately that magnitude in their values. The inputs for our studies are affected by uncertainty of this order of magnitude, due to the set of input data provided.

It is important to highlight that the Total CAPEX used in the calculations includes the CAPEX of the Biogas Plant, as indicated in the tables below. Below are the results of the three scenarios considered for the construction of the Biorefinery intended for bio-methanol production. The results indicate that all scenarios are feasible from a technical, economic, and financial standpoint. However, to adopt a conservative stance and choose the most likely option, we opted to finalize the results with the alternative based on data provided by MeLe.

This scenario presents attractive indicators in terms of Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period.

The reasons for these results, compared to scenarios for Syncrude/SAF production, lie in the lower complexity of construction and operation processes, as well as the market price being lower than the levelized price. The simplicity of technological processes, higher production capacity, and current market price make this option the most viable among those considered.

We emphasize that the analyses and studies carried out by our team covered all processes involved, from biogas and green hydrogen production to obtaining final fuels. Additionally, essential utilities for processes, such as energy and water, were duly considered. To meet the energy demand of the processes, forecasts established by technological studies, including photovoltaic solar energy and wind energy, were included.

It is crucial to highlight that in our analyses and studies, we considered all applicable taxes and duties, as well as exempted incentives of various kinds generally granted to projects in the biogas, green hydrogen, and biofuels segment. Thus, we present adverse and conservative scenarios, providing investors with a broader margin of safety in their investments. It is certain that these projects will benefit from substantial incentives and benefits granted at municipal, state, and federal levels, which will have an even more positive impact on the economic and financial viability of the ventures.

Below, we present the results obtained for the production of Biomethanol based on the three input datasets provided by NIRAS, MeLe, and considering 50% uncertainty.

6.6.3.1 *Biomethanol: Scenario C.1 - Input datasets provided by NIRAS*

Table 6-16 Technical, Economic, and Financial Parameters of Scenario C.1

BIOMETHANOL	Obs.	Scenario C.1 NIRAS Data
CAPEX Total	TCI (biogas, modules, engineering, BoP, civil and contingency) (Millions €)	€ 1,824
OPEX Total	(raw material, plant operations, utilities maintenance, depreciation and interests) (Millions €)	€ 312
Production	(Ton/h)	40.0
Numbers of Hours	(h)	8,117
Production	(Ton / year)	324,680
Euro / Ton		€ 1,500.00
Annual Revenue (A)	(Millions €)	€ 487.02
Biogas Plant		MM€ 530 / 15 anos
Annual installment (B)	(Millions €)	€ 35.33
(A)+(B)		
Year 2 to Year 16	(Millions €)	€ 522.4
Year 17 to Year 20	(Millions €)	€ 487.0
Capital Sources		
Equity (E)	30.0%	€ 547.2
Third Party Capital (D)	70.0%	€ 1,276.8
Income tax (zero % due to applied incentives)	34.0%	-
Inflation	2.0%	-
Cost of internally sourced capital (Ke)	10%	-
Cost of capital from external sources (Kd) (50% development bank + 50% private bank)	6%	-
WACC	$WACC = [Ke\left(\frac{E}{D+E}\right) + Kd\left(\frac{D}{D+E}\right)]*(1-T)$	4.8%

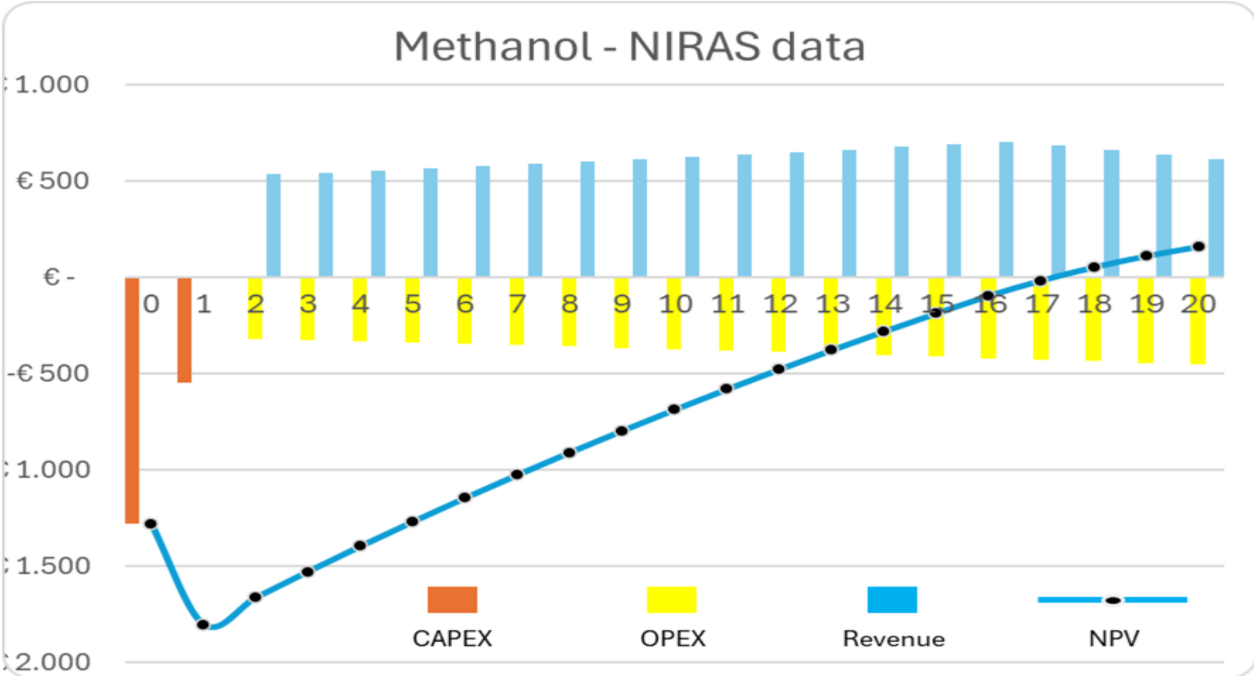

Figure 6-8 Cash Flow of Scenario C.1 - Methanol, NIRAS data

Table 6-17 Analysis of the viability of Scenario C.1

BIOMETHANOL Cenário C.1 – NIRAS Data	
Net Present Value (NPV) (Millions €)	€ 160
Internal Rate of Return (IRR) (%)	5,72%
Payback (years)	17,2 years

6.6.3.2 Biomethanol: Scenario C.2 - Conjuntos de dados de entrada fornecidos por MeLe

Table 6-18 Parâmetros técnico, econômico e financeiro do cenário C.2

BIOMETHANOL	Obs.	Scenario C.2 MeLe Data
CAPEX Total	TCI (biogas, modules, engineering, BoP, civil and contingency) (Millions €)	€ 1,578
OPEX Total	(raw material, plant operations, utilities maintenance, depreciation and interests) (Millions €)	€ 312

Production	(Ton/h)	40.00
Numbers of Hours	(h)	8,117
Production	(Ton / year)	324,680
Euro / Ton		€ 1,500.00
Annual Revenue (A)	(Millions €)	€ 487.02
Biogas Plant		MM€ 530 / 15 anos
Annual installment (B)	(Millions €)	€ 35.33
(A)+(B)		
Year 2 to Year 16	(Millions €)	€ 522.4
Year 17 to Year 20	(Millions €)	€ 487.0
Capital Sources		
Equity (E)	30.0%	€ 473.5
Third Party Capital (D)	70.0%	€ 1,104.9
Income tax (zero % due to applied incentives)	34.0%	-
Inflation	2.0%	-
Cost of internally sourced capital (Ke)	10%	-
Cost of capital from external sources (Kd) (50% development bank + 50% private bank)	6%	-
WACC	$WACC = [Ke\left(\frac{E}{D+E}\right) + Kd\,(\frac{D}{D+E})]*(1-T)$	4.8%

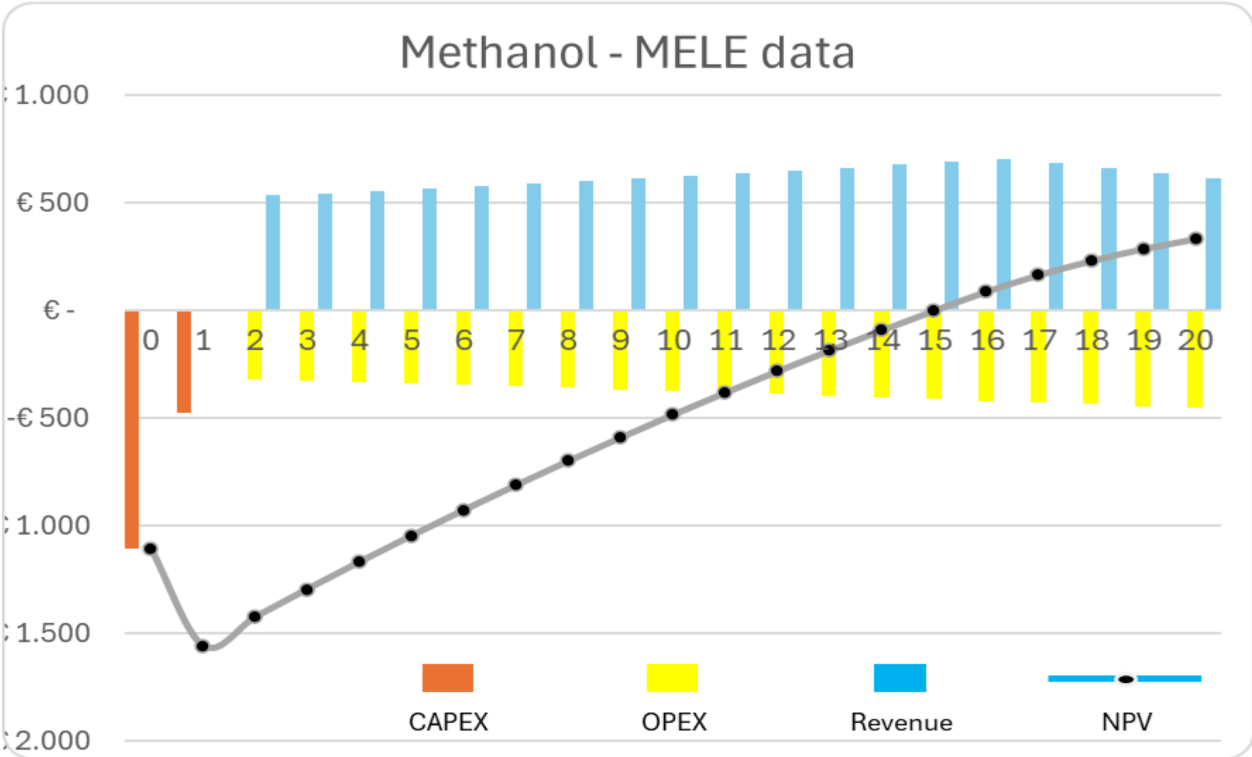

Figure 6-9 Cash Flow of Scenario C.2 - Methanol, Mele data

Table 6-19 Analysis of the viability of Scenario C.2

BIOMETHANOL Cenário C.2 – MeLe Data	
Net Present Value (NPV) (Millions €)	€ 333
Internal Rate of Return (IRR) (%)	6,99%
Payback (years)	15,0 years

6.6.3.3 Biomethanol: Scenario C.3 - Input Data Sets with 50% Uncertainty

Table 6-20 Technical, Economic, and Financial Parameters of Scenario C.3

BIOMETHANOL	Obs.	Scenario C.3 Uncertainty 50% or More probable
CAPEX Total	TCI (biogas, modules, engineering, BoP, civil and contingency) (Millions €)	€ 1,340
OPEX Total	(raw material, plant operations, utilities maintenance, depreciation and interests) (Millions €)	€ 312
Production	(Ton/h)	40.00
Numbers of Hours	(h)	8,117
Production	(Ton / year)	324,680
Euro / Ton		€ 1,500.00
Annual Revenue (A)	(Millions €)	€ 487.02
Biogas Plant		MM€ 530 / 15 anos
Annual installment (B)	(Millions €)	€ 35.33
(A)+(B)		
Year 2 to Year 16	(Millions €)	€ 522.4
Year 17 to Year 20	(Millions €)	€ 487.0
Capital Sources		
Equity (E)	30.0%	€ 402.0
Third Party Capital (D)	70.0%	€ 938.0
Income tax (zero % due to applied incentives)	34.0%	-
Inflation	2.0%	-
Cost of internally sourced capital (Ke)	10%	-
Cost of capital from external sources (Kd) (50% development bank + 50% private bank)	6%	-
WACC	$WACC = [Ke\left(\frac{E}{D+E}\right) + Kd\,(\frac{D}{D+E})]*(1-T)$	4.8%

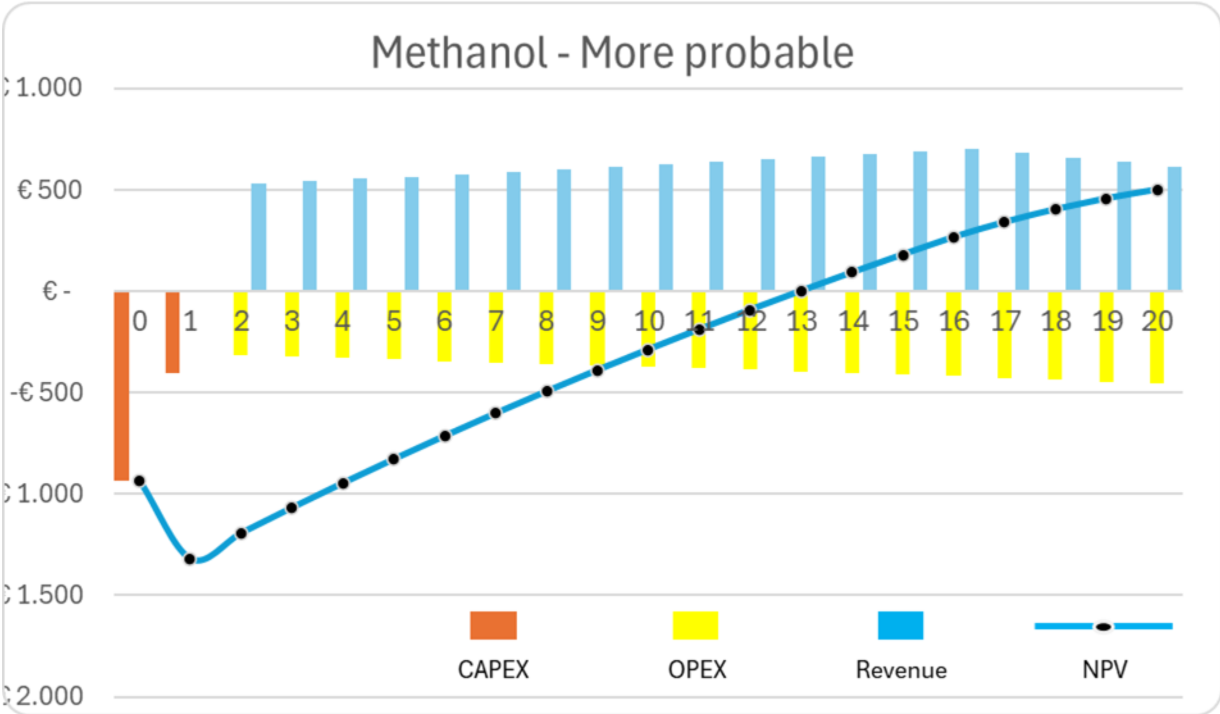

Figure 6-10 Cash Flow of Scenario C.3 - Methanol, Uncertainty Data 50% or Most Likely

Table 6-21 Analysis of the viability of Scenario C.3

BIOMETHANOL Cenário C.3 – Uncertainty Data 50% or Most Likely	
Net Present Value (NPV) (Millions €)	€ 500
Internal Rate of Return (IRR) (%)	8,57%
Payback (years)	13,0 years

6.6.4 Biomethanol: Scenario C.4 - Input Data Sets provided by NIRAS based on latest improved financial analysis

A fourth scenario was developed to integrate various revenue streams based on insights from the Mele report (i.e., fertilizer and carbon credits sale, among others). Updated CAPEX values were sourced from market data and NIRAS' references. An optimization model was implemented to enhance the analysis. Additionally, a more precise WACC was chosen (11%) to improve the accuracy of the financial assessment.

To estimate CAPEX and OPEX, different methodologies were implemented, depending on the level of details of available information and topics knowledge. A more detailed plant design effort has been conducted for the methanol synthesis plant, employing specific process engineering simulation tools (Aspen Plus, Honeywell Unisim), to reach a more detailed description of process components and their sizes. In connection to this more detailed methodology, it was possible to calculate chemical plant components costs individually, following the Guthrie Individual Factor method, obtaining an estimate of the bare module cost. Cost estimates of key components (reformer and APOC reactors), is carried out following either existing quotations or with direct communication with technology providers. Estimates regarding development engineering, site cost, balance of plant, buildings and construction costs and various contingencies are added to the bare modules cost.

Electrolyzer CAPEX has been obtained from Niras internal knowledge and interaction with electrolyzer providers and additional public references. Operative costs for chemical plant and electrolyzer system are calculated based on designed +utilities consumption, it includes electricity consumption, water consumption, catalyst consumption, site and administrative personel cost and maintenance. Additional electricity consumption, provided from the grid, has been calculated employing a dynamic hourly-based model for system operations, with solar radiation and wind load profiles derived from international databases, utilizing the software EnergyPro. Energy consumption profiles resulted from modelling are presented in Figure 6-11 (it is noted that a more detailed dynamic model needs to be developed in the next design phases, to refine and optimize electricity consumptions and chemical compound storage sizes).

In the OPEX, an average electricity price from grid, following Brazilian tariffs has been used. Grid connection together with green electricity PPA should offer a reduced electricity consumption costs compared to just a grid connection tariffs. A dedicated sensitivity analysis on electricity costs is shown below.

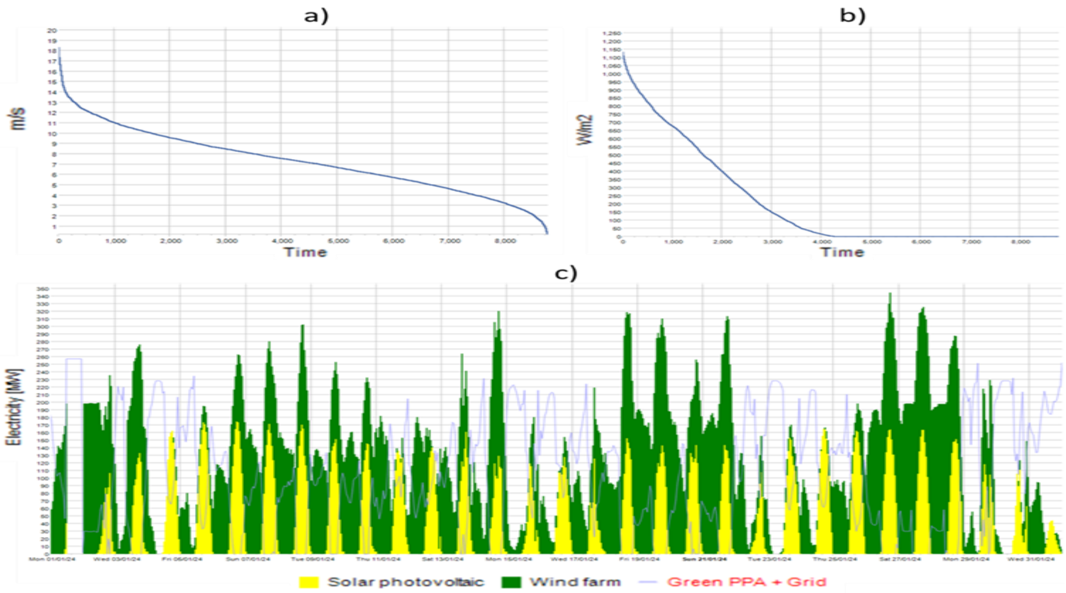

Figure 6-11 a) Western Parana wind potential, cumulative wind speed per hour representation. b) Western Parana solar potential, cumulative power density per hour representation. c) Dynamic model result for plant operation, showing wind and solar production and electricity imported through green PPA grid connection.

Table 6-22 Technical, Economic, and Financial Parameters of Scenario C.4

BIOMETHANOL	Obs.	Scenario C.4 NIRAS improved financial analysis
CAPEX Total	TCI (biogas, modules, engineering, BoP, civil and contingency) (Millions €)	€ 1,496
OPEX Total	(raw material, plant operations, utilities maintenance, depreciation and interests) (Millions €)	€ 225.9
Methanol Production	(Ton/h)	45.00
Numbers of Hours	(h)	7,884
Methanol Production	(Ton / year)	354,780
Euro / Ton		€ 1,484.00
Methanol Sale (A)	(Millions €)	€ 526.58
Biogas Sale for second year (B)	From Mele report, section 20.3.1 & 20.3.2 Shall be considered in revenue before the methanol plant is operational (Millions €)	€ 137.78
Biogas Surplus Sale (C)	Difference between biogas produced and biogas utilized for methanol production (Millions €)	€ 13.1
Fertilizer Sale (D)	From Mele report, section 20.3.1 & 20.3.2 (Millions €)	€ 44.1
Carbon Credits (E)	From Mele report, section 20.3.1 & 20.3.2 (Millions €)	€ 14.4
Electricity Surplus Sale (F)	From EnergyPro model (fig. 7.7) (Millions €)	€ 1.99
Annual Revenue		
Year 2	(B + D + E) (Millions €)	€ 196.30

BIOMETHANOL	Obs.	Scenario C.4 NIRAS improved financial analysis
Year 3 to Year 20	(A + C+ D + E+ F) (Millions €)	€ 600.11
Capital Sources		
Equity (E)	30.0%	€ 448.9
Third Party Capital (D)	70.0%	€ 1047.4
Income tax (zero % due to applied incentives)	34.0%	-
Inflation	1.5%	-
Cost of internally sourced capital (Ke)	28%	-
Cost of capital from external sources (Kd) (50% development bank + 50% private bank)	12%	-
WACC	$WACC = [Ke\left(\frac{E}{D+E}\right) + Kd\,(\frac{D}{D+E})]*(1\text{-T})$	11.1%

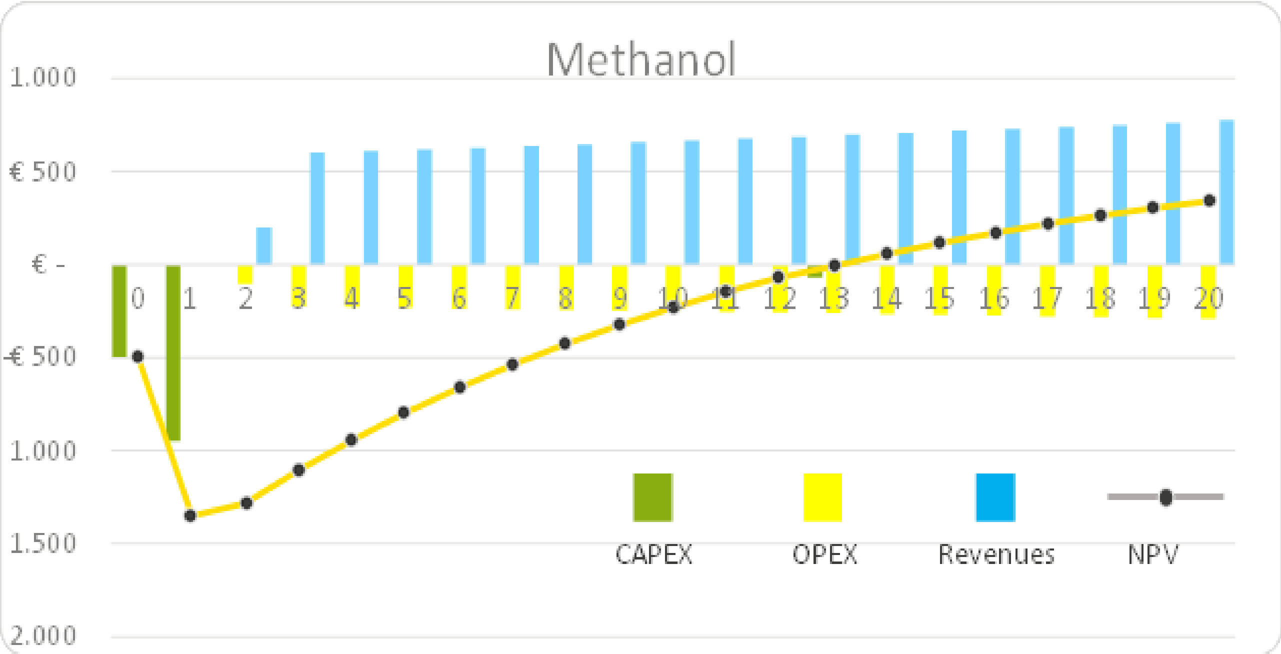

Figure 6-12 Cash Flow of Scenario C.4 - Methanol, NIRAS latest improved financial analysis

Table 6-23 Analysis of the viability of Scenario C.4

BIOMETHANOL Scenario C.4 – NIRAS latest improved financial analysis	
Net Present Value (NPV) (Millions €)	€ 371
Internal Rate of Return (IRR) (%)	14,65%
Payback (years)	12,3 years

A preliminary sensitivity study was conducted using the business cash flow model to evaluate the potential and risks associated with various business scenarios. This study focuses on key variables: capital expenditure (CAPEX), methanol price and productivity, electricity price, and the cost of capital. Three distinct sensitivity cases were analyzed for Niras improved financial analysis scenario : a reference case, a more favorable case and a less favorable one, with a ±15% variation from the reference value. These sensitivity cases aim to provide potential partners and investors with an initial understanding of the business case potential. The impact of these variables is illustrated through essential performance indicators, including Net Present Value (NPV), Internal Rate of Return (IRR), and the Levelized Cost of Methanol (LCOM). The results are presented in Figure 6-13.

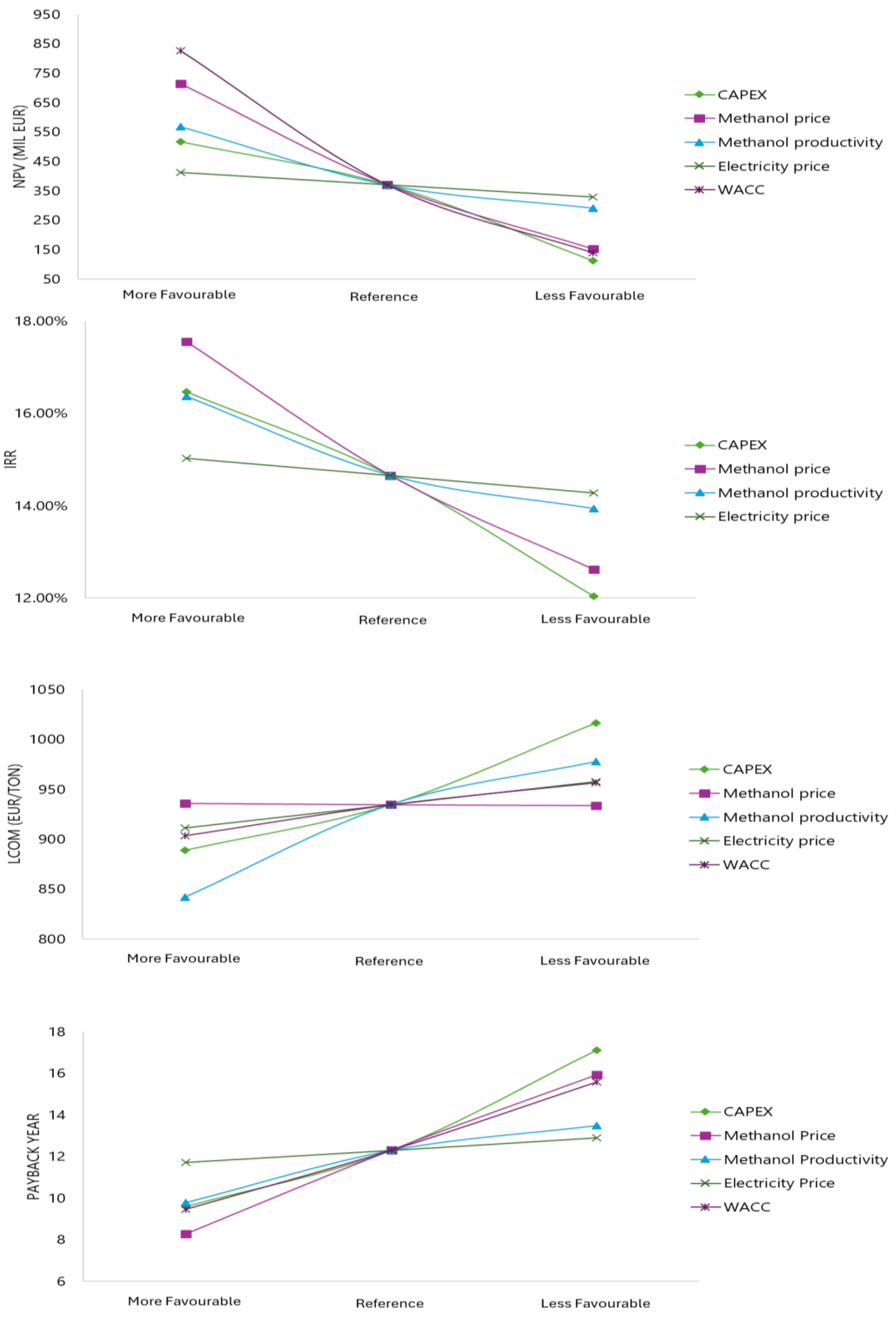

Figure 6-13 Sensitivity analysis of business model: independent parameters evaluated against main business performance criteria

This comparative analysis reveals that CAPEX, the cost of capital (WACC), and methanol price significantly influence the positivity of the business model. These findings underscore the significance of green fuels market and its uncertainty represents the main risk. To better assess the impact of different combinations of methanol price and CAPEX on the internal rate of return, a matrix is proposed

Table 6-24 CAPEX, methanol price comparison and impact on business performance. WACC value kept at 11% as in reference scenario

IRR								
		Methanol Price						
		E-methanol (EUR/ton)	1700	1900	2000	2500	3000	3500
		Bio-methanol (EUR/ton)	1100	1250	1600	2000	2400	3000
		Average	*1287*	*1453*	*1725*	*2156*	*2587*	*3156*
CAPEX (EUR)	1,244,732,872 EUR		15%	17%	20%	25%	29%	34%
	1,464,391,614 EUR		12%	14%	17%	22%	26%	30%
	1,684,050,356 EUR		10%	12%	15%	19%	23%	27%
	1,852,455,392 EUR		9%	11%	14%	18%	21%	25%
	2,037,700,931 EUR		8%	10%	12%	16%	20%	24%

It has been recorded that prices for e-methanol and bio-methanol can reach values in the 3000-3500 EUR/ton range, especially in the maritime transport application. Methanol market prices are therefore currently vastly exceeding IEA and IRENA predictions, mainly driven by supply-demand conditions and green fuels directives. From Table 6-24 it can be clearly evaluated that, almost independently of the CAPEX, with methanol prices above 2000 EUR/ton the business case is extremely favourable.

A similar matrix, shown in Table 6-25, is proposed to evaluate the impact of OPEX costs on business case performance, specifically the IRR, considering various electricity price levels. It is noted that the business model is less sensitive to operating costs. Therefore, even with relatively high electricity prices, the business remains favorable across most methanol price values.

Table 6-25 OPEX, methanol price comparison and impact on business performance. WACC value kept at 11% as in reference scenario

IRR									
			Methanol Price						
			E-methanol (EUR/ton)	1700	1900	2000	2500	3000	3500
			Bio-methanol (EUR/ton)	1100	1250	1600	2000	2400	3000
			Average	*1287*	*1453*	*1725*	*2156*	*2587*	*3156*
OPEX, EUR (El prices)	186,160,273 EUR	0.151 R/kWh (lowest PPA prices)		13%	15%	18%	22%	27%	30%
	208,482,585 EUR	0.275 R/kWh (low range grid prices)		13%	15%	18%	22%	26%	30%
	225,318,625 EUR	0.4 R/kWh (average grid prices)		12%	14%	17%	21%	26%	29%

247,277,067 EUR	0.562 R/kWh (high range grid prices)		11%	13%	16%	21%	25%	29%
272,321,645 EUR	0.75 R/kWh		10%	12%	16%	20%	24%	28%
305,625,605 EUR	1 R/kWh (never registered el. prices)		9%	11%	14%	19%	24%	28%

Lastly, it is of utmost importance to emphasize that during the stages of study development, we dedicated ourselves to a detailed understanding of the project's specifics, gathering initial data, and developing the necessary tools for analysis and preliminary testing. This phase was crucial for comprehending the project's complexity and organizing all the necessary elements to prepare for subsequent stages. This included a thorough assessment of relevant scenarios and an analysis of the impacts of various financing options available.

The presented results include all the spreadsheets mentioned and used in the respective analyses, ensuring a detailed and comprehensive presentation of the obtained data. These tools provide a clear and objective view of the financial projections, enabling an in-depth analysis of the considered scenarios and the potential impacts of the decisions made. This approach reinforces our commitment to transparency and the quality of our work, providing a solid foundation for strategic decision-making.

Alongside this report, we are providing advanced spreadsheet tools that allow our clients to simulate a wide range of conditions by modifying input data and obtaining varied results. These spreadsheets offer a comprehensive and adaptable analysis, essential for guiding the continuation of studies and project development according to identified specific needs.

6.7 Final Considerations

Based on the results of the analyses conducted for this economic and financial feasibility study of the projects in question, we can affirm that the Biogas Central Project of 45 units demonstrates viability and is highly attractive in terms of financial return and environmental benefits.
The choice of the Biomethanol production chain is technically less complex than that of Syncrude/SAF, resulting in reduced associated economic risks and providing greater flexibility. Studies demonstrate an attractive feasibility for this approach.

The technological complexity and high capital investment associated with the levelized price of this biofuel make investment in the Syncrude/SAF plant significantly less attractive and with high financial risk. Therefore, its economic viability is considered unfeasible.

The economic and financial feasibility analysis presents uncertainties due to the need for improvement in detailing the technologies employed. Therefore, further refinement is recommended as the studies progress.
It is essential to emphasize that the results presented reflect conservative scenarios, considering the applicable rates and taxes for a project of this nature. However, it is important to note that bioenergy projects, especially involving biogas, biomethane, green hydrogen, and biofuels in general, are supported by exemptions and incentives that can make the project even more attractive.

We express a highly favorable opinion on the realization of this investor partnership in the projects, highlighting that the project benefits from intrinsic support from public, private, and academic institutions, making it of great importance for regional, state, and national development towards sustainability. Furthermore, this initiative strengthens ties between Brazil and Germany, providing mutual benefits in terms of environmental, economic, and social aspects for both countries, including positive impacts on local and global decarbonization.

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7 H2UPPP: PRE-FEASIBILITY, CERTIFICATION AND ANIMAL WELFARE STUDIES FOR SUSTAINABLE HYDROGEN DERIVATIVE PRODUCTION PILOT PLANT IN PARANA, BRAZIL AND SYNCRUDE PLANT IN TOLEDO, GIZ (PN: 21.9016.3-021.01)

AUTHOR
Jörg-W. Fromme

7.1 Introduction and background

7.1.1 Background

The German Biogas company mele has initiated a large biogas project in Parana/Brazil. The project solves the environmental manure problem and provides biogas as a source to produce towards methane, SAF and Syncrude. For the renewable energy (electricity) production mele has joint forces with ENERTRAG.

The prefeasibility phase is supported by BMWK's H2Uppp, implemented by GIZ. Within this PPP, GIZ has commissioned a comprehensive technical study and a local as well as international financial consultancy.

7.1.2 Tasks

The tasks for the international financial consultancy presented in this report are as follows:

- Support on delineating a strategy for the project financing for the business models
- Assessment of international financing options for the project (including banks, grants, etc.)
- Recommend financing options according to previous assessments
- Elaboration of a checklist for the documentation required by most eligible finance mechanisms
- Provide inputs on the requirements to the project teaser for potential investors and financiers
- Provide inputs for the modelling of economical scenarios.

Based on the a.m. ToR within the framework, this report presents the outcome of the international consultancy. The Input for the project teaser is presented in 0, the Input for the financial modelling has been provided as presented in 0.

7.2 Project and Business Model

7.2.1 The project

The company mele Energietechnik GmbH has been operating successfully in the field of biogas plants in Brazil for many years. It is currently developing a project to produce biomethane on a large scale from liquid manure biogas, hydrogen from renewable energies and ultimately green methanol (alternatively) syncrude with hydrogen for export to Germany.

This multi-stage value chain requires investments totaling over all parts of the project between € 1.4 and € 1.8 billion.

Further details are described in the project teaser and then in the NIRAS report.

7.2.2 Off-taker

Project finance for such a project entire depends on the cash flow generated from the off-take agreement signed by the SPV.

The main requirement for investors and banks is the financial solidity of the off-taker.

Furthermore, the following issues play a role:

- Duration of the Off-take agreement must correspond to the financing period
- Price risk should be excluded / mitigated
- Inflation may be covered by indexation in a cost-plus agreement.

Discussion with international off-takers such as Maersk or Evonik are currently under way.

7.2.3 Financing needs

7.2.3.1 Project development phase

Regarding the project development phase, the following further activities need to be undertaken until Final Investment Decision (FID) and financial closing:

Technical feasibility study

- Transport linkages between different parts of the value chain
- Licensing

ESG studies

- EIA
- Other

FEED to assure technical optimisation and a minimum level of accuracy of CAPEX / OPEX
Legal fees

- All type of contracts
- Licenses.

Fees for the bank also need to be taken into consideration.

The total funds required for the project development phase may well amount to € 10 million to € 20 million.

7.2.3.2 Investment phase

The project developers, mele and ENERTRAG with the support of NIRAS, have estimated the total CAPEX of the project, as defined above, amounts to € 1.6 billion.

Of this, it is estimated that between 40% and 60% are estimated to occur as local costs.

7.3 Project financing

7.3.1 The logic of international project finance

Project finance is a means of financing a company created for the specific purpose of owning, constructing and operating a project, with limited or no recourse to that company's shareholder. Project finance is structured in a way that enables financing from multiple sources of capital, or multiple investors, against repayment from the company's future cash flows.

For project finance a project company (SPV) is established as a new, legally distinct, and ring-fenced entity specifically for the purpose of owning, constructing, and operating a project. This entity is a referred to as a special purpose company, special purpose vehicle or special purpose entity since it was created for a specific purpose.

The general simplified structure of the project around the SPV is illustrated below.

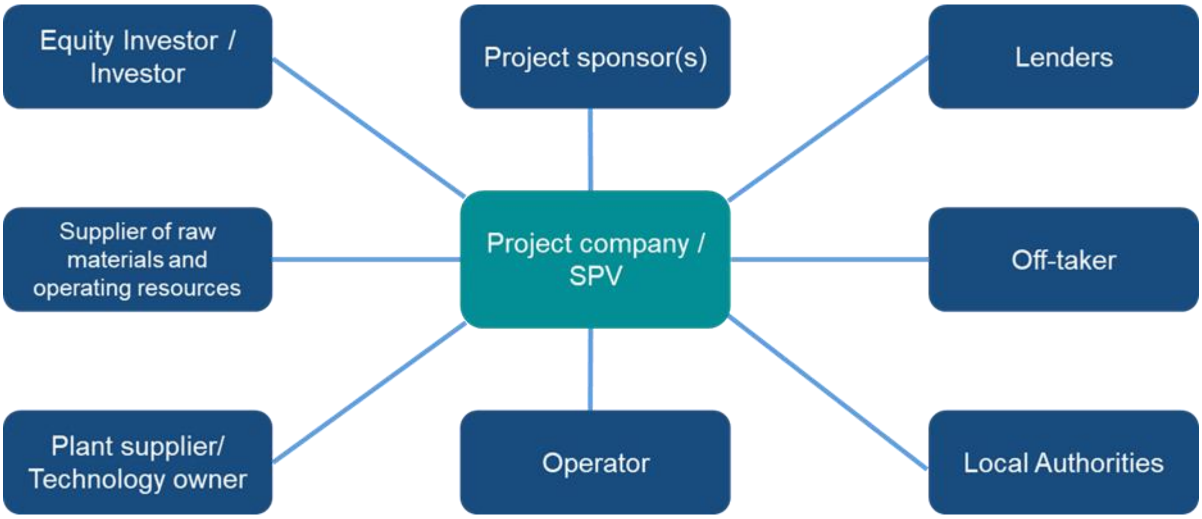

Figure 7-1 Structure of project finance

7.3.2 Financing structure

In the following a financing structure for this specific biogas-to-methanol project has been developed below.

7.3.2.1 Equity

One of the major tasks of the Project developers (NIRAS, mele, ENERTRAG) in the current phase will be finding strong equity partners with sufficient balance sheet capacity and sector experience. Investors should see the project as an opportunity fitting into their overall strategy. Preferably investors consortia should consist of both Brazilian and international investors.

A key question for this project is where that equity shall come from:

- Project sponsors: Developer(s), utilities, or other companies with a long-term stake in the project contribute equity capital.
- Institutional investors: Infrastructure funds, pension funds, or other investors seeking long-term returns might participate.

As mentioned above project for complex technology driven projects will be required between 20% and 30%. The percentage will finally be up to the lenders' requirements and be determined by the financial covenants (e.g. debt service cover ratio, loan life cover ratio) of the financial model. Equity should be paid into the SPV upfront, alternatively it could be injected pari passu with debt financing to the extent the investors will provide security for their equity portion.

For approaching potential equity partners the Project Developers need to have prepared the prefeasibility level with a preliminary business plan as well as a basic financial model, which is currently ongoing.

7.3.2.2 Debt

The major type of debts for such a project finance are:

- Senior long-term debt: Provides the first layer of secured financing, typically from development finance institutions and/or commercial banks, assured by export credit agencies
- Mezzanine debt: Offers higher risk and return profiles compared to senior debt, appealing to certain investors like specialty funds or infrastructure debt funds
- Project bonds: Selling bonds in the capital markets can raise larger amounts of debt but requires a strong project profile and investor confidence. A project bond is a debt security that pays investors on a fixed schedule from the proceeds of the project, being the future cash flows of the project company. This financing tool has not yet been widely used in many emerging markets but has the potential to become a viable means of financing as energy markets mature and become more attractive to capital market investors. Many of these are often institutional investors searching a lower risk.

7.3.3 Foreign versus local currency

Projects such as the biomass-to-methanol project can be financed in either local currency or foreign currency. Local currency is the currency of the jurisdiction in which the project is to be constructed and operate, and foreign or reserve currency is a currency held in significant quantities as part of governments' or institutions' foreign exchange reserves. Reserve currencies, like U.S. dollars and Euros, are commonly used in energy and infrastructure transactions.

Reserve Currency Financing as the Status Quo in emerging markets, energy and hydrogen power projects are typically entirely, or mostly, financed in foreign currency. It may not be possible, due to liquidity constraints and market availability, to finance long-term debt in local currency in the magnitude required by such large projects.

Specifically, debt providers, such as international commercial banks, IFIs, ECAs, are often unable to lend in local currency in most emerging markets. Certain IFIs can provide local currency financing, but typically, local banks are the best source of local currency-denominated debt.

7.3.4 Foreign versus local currency

To achieve financial closure of the project a risk management plan and clear mitigation strategies need to be provided. The risks perceived by financiers can be illustrated as follows:

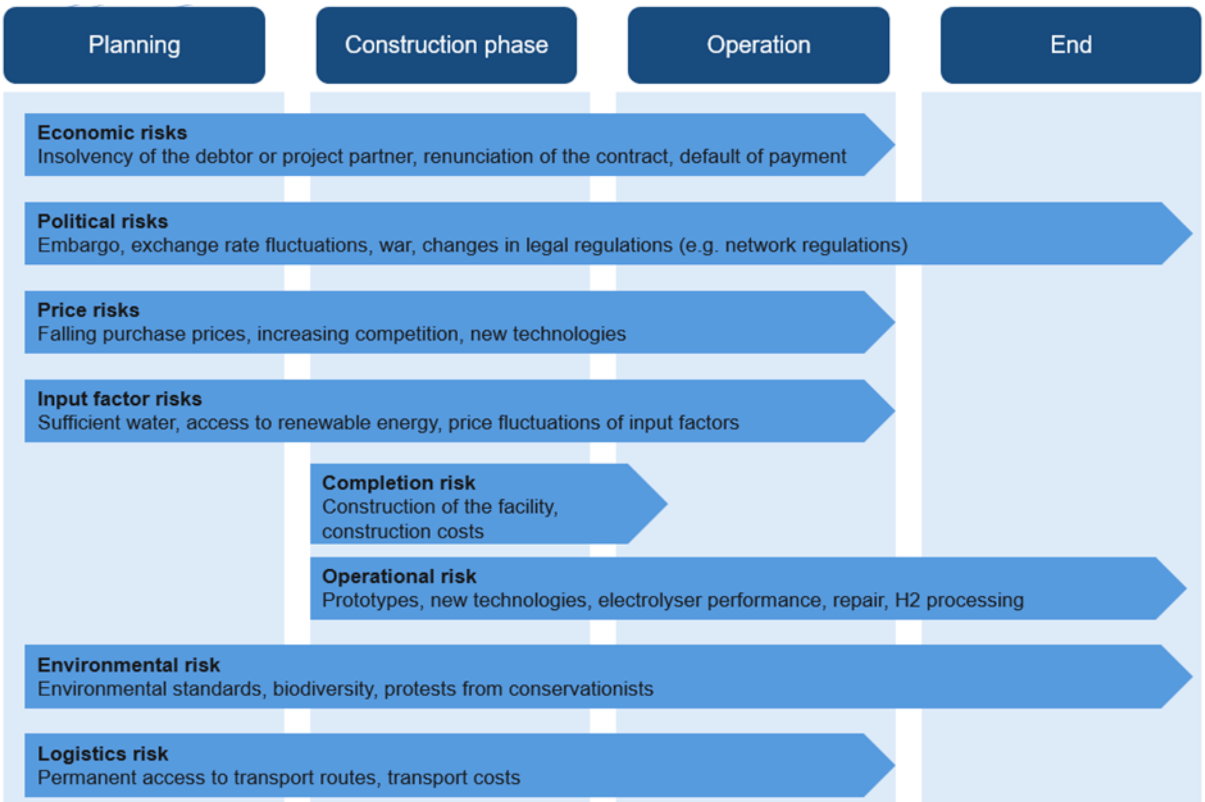

Figure 7-2 Structure of main risks

To mitigate the risks, political risks export credit insurances and investment guarantees are very common; these are available from the German government (HERMES / PWC).

Several types of insurance are crucial for mitigating other risks associated with large international renewable energy projects (IPPs). The specific types can vary depending on project characteristics, location, and financing structure, but some common ones include:

- Construction:
    - Contractor's All-Risk Insurance (CAR): Covers physical damage to the project during construction, including property damage and material damage.
    - Erection All-Risks Insurance (EAR): Similar to CAR but focused on equipment installation and commissioning.
    - Delay in Start-Up (DSU) Insurance: Protects against financial losses due to delays in project completion exceeding a specific timeframe.
    - Advance Loss of Profits (ALOP) Insurance: Covers lost profits if the project experiences a major event during construction that delays commercial operation.
- Operational:
    - Property Damage Insurance: Covers physical damage to the project assets post-construction, including natural disasters, fire, and equipment breakdown.
    - Business Interruption Insurance: Compensates for lost revenue and profits due to an insured event causing operational downtime.
    - Political Risk Insurance: Protects against losses due to political events like expropriation, currency inconvertibility, or war.

- Grid Interruption Insurance: Covers financial losses caused by grid outages or curtailment of power production.
- Environmental Impairment Liability Insurance: Provides financial protection for cleanup costs and damages arising from accidental pollution or environmental damage caused by the project.

- Additional considerations:
  - Cybersecurity Insurance: Becoming increasingly important due to the growing risk of cyberattacks on critical infrastructure projects like renewable energy IPPs.
  - Performance Guarantee Insurance: Can be required by lenders or project off takers to ensure developers meet contractual obligations related to energy production or performance guarantees.
  - Contingent Business Interruption Insurance: Covers loss of income to other businesses dependent on the project's output, for example, nearby factories relying on its power supply.

7.3.5 Currency management

7.3.5.1 3.4.1 Currency requirements

Being a project with both Brazilian and international stakeholders as well as cash flow streams within the country and across the border, at least two, possibly even three currencies will be involved in the project. Capital expenditures, operating expenditures and revenues are denominated either in local currency (Brazilian Real) or in foreign currency (Euro or/and U.S. Dollar), at different percentages:

Table 7-1

		Euro	Real
Revenues for Final Product (International Off-taker)		100 % [?]	[?]
Biogas Plant	CAPEX	10-15 %	85-90 %
	OPEX	5 %	95 %
Methanol Plant	CAPEX	70 %	30 %
	OPEX	5-30 %	70-95 %
Renewable Energy Plant and Electrolyzer	CAPEX	75 %	25 %
	OPEX	10 %	90 %

Experience shows that the external value of the real can fluctuate considerably over time, as has been the case over the last ten years, for example:

Figure 7-3 Exchange EUR-BRL over the last 10 years

Main factors for FX fluctuations are: (i) differences in inflation; (ii) balance of payments imbalances; (iii) economic growth; (iv) interest rate differences (iv) political (in)stability (v) external shocks, such as the corona epidemic (2020/21).

The Brazilian Central Bank generally follows a floating exchange rate regime and may intervene only when necessary to guarantee the functionality of the FX market and to reduce excessive volatility.

However, as compared to other currencies in the region the Brazilian Real is seen as relatively stable. The Real dominates the Latin American currency market, due to the size of the Brazilian economy.

7.3.5.2 Options to manage currency risk

As there are no fixed exchange rates between Real and Euro/U.S. Dollar, the stakeholders potentially face currency risks in case of a currency mismatch between incoming and outgoing cash flows. For instance an international off taker pays in hard currency (Euro or U.S. Dollar) for methanol / syncrude in line with the world market, but on the other hand the seller of this product needs to cover its operating cost in Real („Transaction Risk"). Moreover, the balance sheet of an international investor holding shares in a Brazilian company will be affected by a devaluation of the Real which will reduce the value of its shares („Translation Risk").

Transaction risks could be managed by (i) natural hedging which is maximizing the match between cash inflows (sales) and cash outflows (OPEX, debt service for CAPEX) in one currency as much as possible; (ii) applying hedging instruments for the remaining mismatch, such as currency swaps offered by banks.

The currency of cash flow streams between the various stages of the project will be a matter of negotiations among the various parties. One factor will be the minimization of currency transaction risks.

Different stakeholders, i.e. international off-takers, local off-takers, international investors, local investors, international banks, local banks, are affected differently. Also, their policies regarding currency risk management may differ. Usually, stakeholders are willing to take transaction risks to a certain extent. Finally, it is a matter of balancing remaining currency risk and cost of currency risk mitigation.

7.4 International Financing Sources of the Project

7.4.1 International financial institutions

The following is an assessment of the international financing sources of funding for the project.

7.4.1.1 KfW (PtX platform)

KfW manages the BMZ's PtX Development Fund for developing countries and emerging economies.

The PtX Development Fund of € 270 million aims to promote public organizations and private companies in developing countries and emerging economies where the conditions for green hydrogen are particularly good. Investments in PtX projects are supported with a mix of grants and other financing instruments from KfW Group. In this way, the fund improves the financing options for the production, transport and use of green hydrogen in the partner countries. At the same time, it strengthens their local economy and supports them in establishing the future PtX technology at an early stage. This gives the countries a connection to an important technology and economic sectors - without the funding, there is a risk that the countries might be "left behind".

PtX Development Fund allocates grants for capital expenditure such as construction, installation, modernization or expansion of infrastructure of Power-to-X projects in order to make them bankable. Supplementing PtX Development Fund, a broad range of innovation and investment financing can be provided by KfW Group's PtX Platform. Serving as a one-stop-shop, KfW's PtX Platform offers a broad range of financing instruments, including grants, promotional loans, equity and debt financing as well as mezzanine financing including KfW's three business areas DEG, IPEX and KfW Development Bank.To this end, the platform bundles promotional, and financing offers from the German Federal Government and KfW Group and puts together a suitable package of financing from the toolbox of instruments on offer. KfW also helps to bring other public and private financiers "on board". The goal is to stimulate the market ramp-up of green hydrogen and contribute to the decarbonization of the global economy.

The management of the fund has been entrusted to asset manager KGAL. A first call for expression of interest has been launched at the end of 2023. Brazil is among the six countries addressed.

7.4.1.2 DEG

DEG is the private sector finance subsidiary of the KfW banking group. DEG has ample experience with the financing of renewable energy IPPS and syndicates loans.

Regarding the financing of hydrogen, DEG works closely with KfW's PTX Development Fund.

7.4.1.3 EIB

The European Investment Bank (EIB) is the bank of the European Union and the largest multilateral financing institution in the world. Each member state holds a share in the EIB's capital. Overall, however, the EIB is financially independent. It raises the funds for its work through bonds on the capital markets. The EIB's main focus is climate protection. Here it is committed to supporting the European Green Deal and helping Europe become climate neutral by 2050. This will require trillions of Euros in investments. The EIB also focuses on development, innovation and knowledge, the Euro, small and medium-sized enterprises, and infrastructure and cohesion.

The EIB provides capital in the form of loans and project financing of up to around € 250 million as well as through equity investments and funds. In the area of project development, the bank provides support.

In Brazil, EIB is involved in the Global Gateway hydrogen project "Green Energy Park" in the state of Piauí which shall export hydrogen to Croatia in order to then pipe it further to Central Europe.

Furthermore, EIB is managing the € 459 million Green Hydrogen Trust Fund with budget of the German BMWK. This fund shall co-finance projects by capital subsidies and project development.

7.4.1.4 World bank / IFC

The International Finance Corporation (IFC) is the private sector arm of the World Bank Group and offers loans as debt capital above an amount of U$ 20 million for seven to 12 years. It also offers equity capital and mezzanine capital for 5-20% of the investment sum. Required is at least 30% equity share of the investor; the bank only acquires minority interests of up to a maximum of 20%.

IFS has already engaged in green hydrogen projects such as

- South Africa: In 2022, the IFC invested US$ 40 million in HyGreen Africa, a South African green hydrogen company developing a 100 MW electrolyser plant for clean fuel production.
- Egypt: The IFC partnered with the Egyptian Green Hydrogen Alliance to support the development of a green hydrogen ecosystem in the country. This includes a feasibility study for a 100 MW green hydrogen production facility.
- Portugal: The IFC invested € 40 million in H2Sines, a green hydrogen project in Portugal focused on renewable energy production and hydrogen production for transportation and industrial use
- Netherlands: The IFC joined forces with Nederlandse Waterschapsbank (NWB) to launch a € 200 million green hydrogen financing facility supporting Dutch SMEs involved in the sector.

7.4.1.5 IDB

The Inter-American Development Bank (IDB) is owned by its member states, some of which have the status of "borrowing countries", while others are "recipient countries". They are entitled to receive funding from the IDB. The IDB also finances private sector projects. This includes, for example, promoting the hydrogen economy in the Caribbean and Latin America. In addition to traditional financial instruments, IDB Invest also offers technical and advisory support and, if available, can tap donor funds to finance key projects.

The IDB offers senior and subordinated loans of up to US$ 200 million (in exceptional cases up to US$ 400 million) for larger project and corporate financing of ecologically, socially, economically, or financially sustainable projects. However, the financing share cannot generally exceed 33% to a maximum of 40% of the project costs. Equity investments of up to a maximum of 33% and US$ 10 million are also conceivable.

As the other IFIs, IDB is aiming to finance green hydrogen in Latin America. A first major loan has been extended to Chile's economic development agency Corfo together with other IFIs.

Brazil and the (IDB) have initiated the creation of a unique financial solutions and hedging platform aimed at reducing foreign exchange risk for investments aligned with socio-environmental principles and climate change adaptation and mitigation. These innovative tools seek to attract green investments within Brazil's Green Transformation Plan. Initially, the platform has the potential to mobilize coverage of up to US$ 3.4 billion, a figure that may increase over time.

7.4.2 Cost of financing

Regarding the financial structuring it should be considered that most of the capital varies between the different sources and mounting in the following order:

- IFIs concessional finance
- Public banks commercial finance based of Euribor or Libor topped up with a margin reflecting the county and project risk of 1.5 to 4%
- Commercial banks, as above with a higher margin
- Equity investors

To be differentiated between strategic investors with additional interest in the project e.g. off-taker, depending on country and project specific risk profile roughly about 12% to 18%.

Fees for the bank also need to be taken into consideration. Banks normally charge:

- A management fee of 1% – 2.5%
- A commitment fee of 0.35% – 0.5%.

7.4.3 Investigating possible sources of private capital

7.4.3.1 Hydrogen funds

- Copenhagen Infrastructure Partners (CIP)
  - CIP is an investor for projects from the development phase onwards; investments are made in hydrogen projects, particularly in Europe, but other countries such as Chile, Morocco and Oman are also possible. Due to the need to create the associated infrastructure for hydrogen projects, investments are only made in large projects that operate in the gigawatt range. Investment volumes in the projects average around € 2 billion.
    An example of the engagement of CEP is Alisios Potiguares Offshore Wind Farm, a 1,845 MW offshore wind power project in the Brazilian state of Rio Grande do Norte. The project is co-owned by Bosford Participacoes and Copenhagen Infrastructure Partners KS, with their respective ownership stake of 50% each. The project construction is expected to commence from 2025. Subsequent to that it will enter into commercial operation by 2029[19].

- Hy24
  - Hy24 is established in 2021 is specifically aimed at green hydrogen projects with the aim of promoting the development of a hydrogen economy according to strict environmental, social and governance (ESG) criteria. A particular focus is on so-called “first mover investments”, i.e. on particularly new technologies, ideas or products that have not yet been found on the market in this form. Hy24 was initiated by French industry in partnerships with companies like ENGIE and Air Liquide and has currently invested more than € 2 billion.

- Climate Investor One20

[19] Power Technology.Power plant profiles:Alisios Potiguares Offshore Wind Farm, Brazil, retrieved on 22 March 2024

[20] Climate Fund Managers, History.

- Climate Investor One (CIO) is a fund with the participation of the Dutch development bank Nederlandse Financierings-Maatschappij voor Ontwikkelingslanden N.V. (FMO), WWF NL, the Dutch Fund for Climate and Development and private financiers.
  The fund has a technological focus on renewable energy infrastructure projects (wind, hydropower, solar PV). While public financiers support the development phase, private donors finance the project phase.
  The fund is divided into three phases. During the development phase, US$ 50 million is available for planning and development loans and technical support. In the construction phase, around US$ 800 million will be reserved for construction to support projects with up to 75% equity participation. Senior debts are issued for the implementation phase. A further US$ 800 million is available for this purpose.
  The minimum ticket size for this fund is US$ 10 million and the equity requirement for the sponsor is usually at least 25%.
  Climate Investor One, a 2015 Global Lab instrument, launched in partnership between FMO, the Dutch Development Bank, and Sanlam Infraworks of South Africa, provides funding for renewable energy projects in the wind, solar and run-of-river hydro sectors in developing countries across Africa, Asia and Latin America. CIO comprises three separate, but operationally interlinked funds: the Development Fund, the Construction Equity Fund and the Refinancing Fund, each tailored to finance a stage in the project's lifecycle: development, construction and operations.[21]

7.4.3.2 *Other funds*

Off-takers often take a position – sometimes and preferably equity.

Due to the size of the project the classical equity partners such as family offices will not become relevant.

- Green climate fund's "Global Subnational Climate Fund"[22]
  - The fund is aimed at medium-sized projects that are not the responsibility of national authorities but of regional authorities. Investors include IUCN and Pegasus Capital Advisors.
    The fund volume is US$ 750 million; of these, US$ 150 million will be provided by the GCF. In total, 20% of the capital is publicly financed, while 80% comes from the private sector. Investment volumes in individual projects range between US$ 5-75 million.
    In addition to equity investments of 10-20% for project implementation, the fund will provide an additional US$ 18.5 million for technical support to develop bankable projects.
    A total of 11 projects were conducted in Brazil for a total GCF financing amounting to U$ 421.4 million.

- Macquarie
  - Macquarie is a global financial services group founded in 1969 headquartered in Australia. They offer a wide range of financial products and services, with a focus on the following areas:
    - Asset Management: Managing investment funds for institutional and individual investors across various asset classes like infrastructure, real estate, and private equity.
    - Banking and Financial Services: Providing corporate and institutional banking services, including lending, trade finance, and foreign exchange.

[21] The Lab, Climate Investor One, retrieved on 25 March 2024

[22] Green Climate Fund, Green Climate Fund, retrieved on 25 March 2024

- Commodities and Global Markets: Trading and risk management services for commodities like energy, metals, and agricultural products.
- Macquarie Capital: Providing advisory and capital raising services for mergers and acquisitions, IPOs, and debt financing.

IN Brazil Norsk Hydro, a Norway-based aluminium and renewable energy developer, has agreed to form a joint venture (JV) with Macquarie Asset Management to develop renewable energy projects.[23]

Macquarie will form the JV with Hydro's renewable energy company, Hydro Rein.Hydro will own 50.1% of the JV and Macquarie will own the remaining 49.9% by investing $332m (Nkr3.7bn). The investment from Macquarie will be used by Hydro Rein to fund current projects under construction and develop its pipeline in the coming years.

The two are currently developing the 586MW Feijão combined wind and solar project in Brazil. This project will support Hydro's bauxite mine, Paragominas, and its alumina refinery, Alunorte, with a clean electricity supply.

7.5 Carbon Finance in the voluntary market

Biogas from pig manure decomposition releases methane (CH4), a potent greenhouse gas. Capturing this biogas and converting it to biomethane reduces methane emissions that would otherwise escape into the atmosphere. In voluntary emissions trading, companies or investors primarily finance climate protection projects in developing and newly industrializing countries that reduce emissions there. In doing so, they compensate for CO_2, i.e. carbon dioxide, that they may generate themselves. In contrast to mandatory CO_2 markets such as European emissions trading system (ETS), voluntary emissions trading has no centralized government institutions or authorities that coordinate and regulate the issuing and trading of CO_2 certificates Certified Emission Reductions (CERs).

The Certified Emission Reductions (CERs) would be based on the quantified amount of methane emission reduction achieved by the project.

Biogas to biomethane projects using pig manure can potentially generate CERs (for the voluntary market), but there are specific accounting considerations involved. Here's a breakdown.
Emission reductions generated

Biogas from pig manure decomposition releases methane (CH4), a potent greenhouse gas. Capturing this biogas and converting it to biomethane reduces methane emissions that would otherwise escape into the atmosphere.

The CERs would be based on the quantified amount of methane emission reduction achieved by the project.

- Accounting methodology
    - CDM methodology AMS-III.G: This methodology under the Clean Development Mechanism (CDM) is specifically designed for "grid-connected electricity generation from biogas from waste." It can be adapted for this biogas to methanol project with adjustments specific to pig manure.
      The methodology requires calculating baseline emissions (methane released without the project) and project emissions (methane captured and converted to biomethane). The difference represents the emission reduction that generates CERs.

The main challenge will be to prove additionality: Greenhouse gas mitigation projects such as these must ensure that their reduction / avoidance is additional. This means that the biogas project would not have been implemented

[23] Hydro. News. Hydro Rein and Macquarie Asset Management become partners to develop more renewable energy for industries, retrieved on 25 March 2024

without the expected proceeds from the sale of the certificates. Measures that are already economically viable in themselves and would therefore have been implemented anyway are therefore not eligible for compensation (financial additionality).

An economic analysis would need to show that only the revenues from selling CER pushes C=2 over the profitability threshold. This would have to be undertaken for the overall green methanol project as the biogas for electricity or similar could be economic without the revenues from CER.

For this type of consideration, a price of about US$ 4 to US$ 8 U/ ton should be considered, in fact renewable energy project tend to fetch lower prices than agriculture.

In addition to the certified savings, it will be important in future that host countries (the countries in which the project takes place) agree to trade. The background to this is that since the Paris Agreement, all signatory states have binding reduction targets. The CAs are intended to prevent savings achieved from a project from being counted twice: Namely, once within the framework of the national CO_2 reduction targets of the developing countries and once within the framework of the compensation of the buyers (often in industrialized countries). Both Article 6.4 of the Paris Agreement and, in future, the gold standard require the consent of the host country Brazil. One will have to see how the Brazilian policy emerges in this respect.

7.6 Export finance

7.6.1 Sellers' s credit

Export finance through seller's credit is a financial arrangement where the seller of goods or services extends credit to the buyer, typically in the form of a loan, to facilitate the export transaction. This type of financing is often used in international trade when the buyer requires additional time to pay for the goods or services purchased.

For the Biomass-to-Methanol Project suppliers for wind turbines or EPCs for the methanol production. They then refinance to European interest levels.

Export finance by means of supplier's loans can have long tenures and can be insured by export credit agencies (ECA) up to 22 years (see below).

7.6.2 Buyers' loan

Export finance through buyer's loan involves the buyer obtaining financing from a financial institution to facilitate the purchase of goods or services from an exporter. This type of financing is commonly used in international trade when the buyer requires additional funds to complete the transaction.

The exporter obtains his payments through his corresponding bank upfront. This loan can also be insured by ECAs.

7.6.3 UFK financing

The import of raw (critical) materials including green hydrogen and its derivates to Germany is supported by a government scheme which insures untied financial loans (Ungebundene Finanzkredite – UFK) these loans are extended by (German) banks to the hydrogen production companies (SPV).

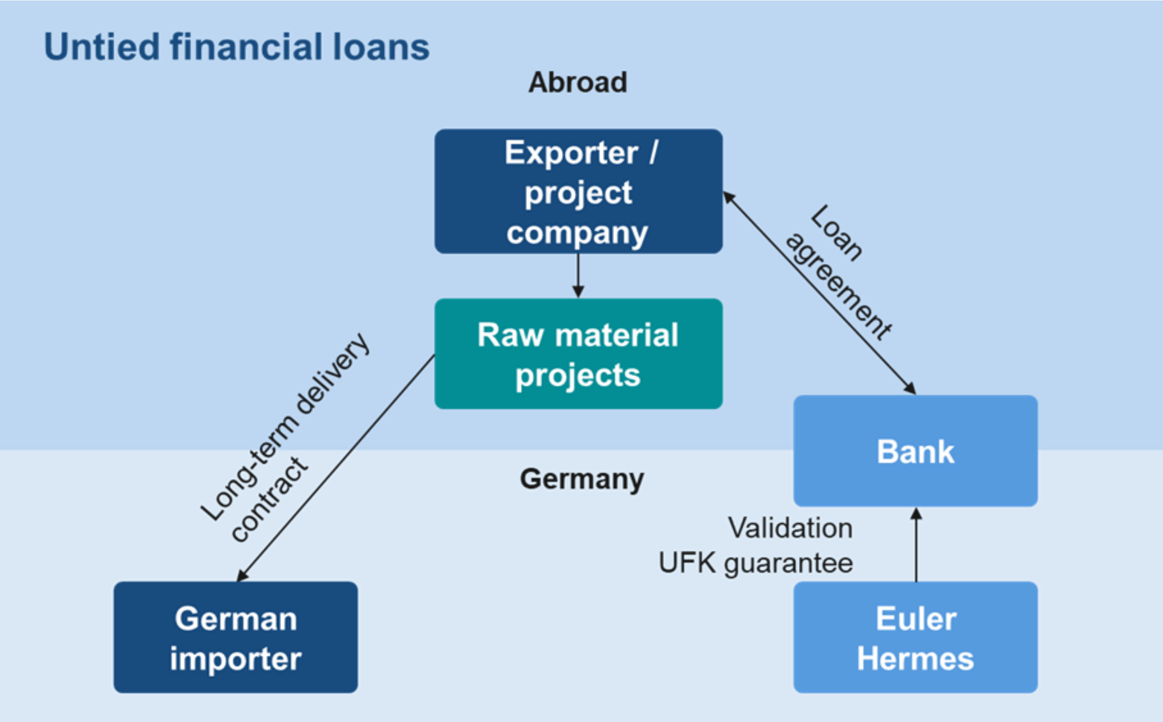

Figure 7-4 Structure of UFK Finance and its insurance

It shall thus be beneficial if the off-taker for green methanol is a German importer so that the SPV can integrate such a loan into the debt part of financing structure.

In this case the UFK guarantee of the German government can be used to lower risk and this interest rates for commercial banks to the SPV.

7.6.4 Export credit insurance

For practically all international financing for developing and emerging countries such as Brazil banks require export credit insurances. Export credit insurance is given by the German as well as other governments for both buyers and sellers credits.

The German ECA Euler Hermes covered the following risks.

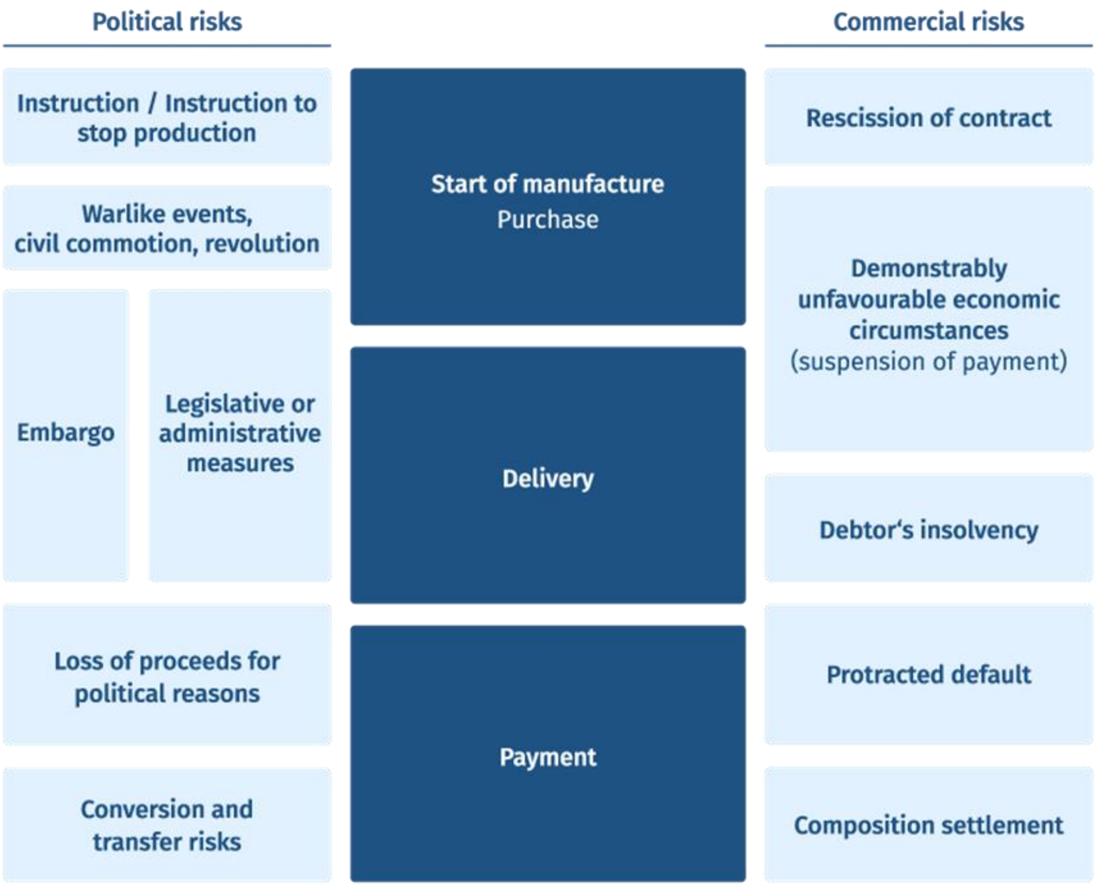

Figure 7-5 Risks covered by export credit guarantees

7.6.5 Investment guarantees

Investment guarantees provided by the Federal Republic of Germany refer to financial assurances and protection offered by the German government to encourage and support investments made by German companies in developing countries, and emerging markets. These guarantees aim to mitigate risks associated with political instability, expropriation, currency inconvertibility, and other potential adverse events that may affect the investment.

The commercial risk of the Biomass-to-Green Methanol could be included if the off-taker is public. This could apply in the case of PETROBRAS becoming the off-take e.g. for methanol.

7.7 Financing structure proposed

Summarizing the above, the financing should be structured basically along the lines given below. The following enumeration is project-specific where project-specific information is available, otherwise it is more general.

7.7.1 Different stages of the project

The project will consist of three subprojects, i.e. biogas production, renewable energy generation and chemical production of biogas derivatives. Given the variety of technologies in the project as well as the differences in the background and in the interests of the various investors each production stage would require a separate project company (Single Purpose Vehicle) specifically established for that stage. That means that basically there will be the following three SPVs: (a) Biogas, SPV (b) Renewable Energy SPV (c) e Methanol SPV.

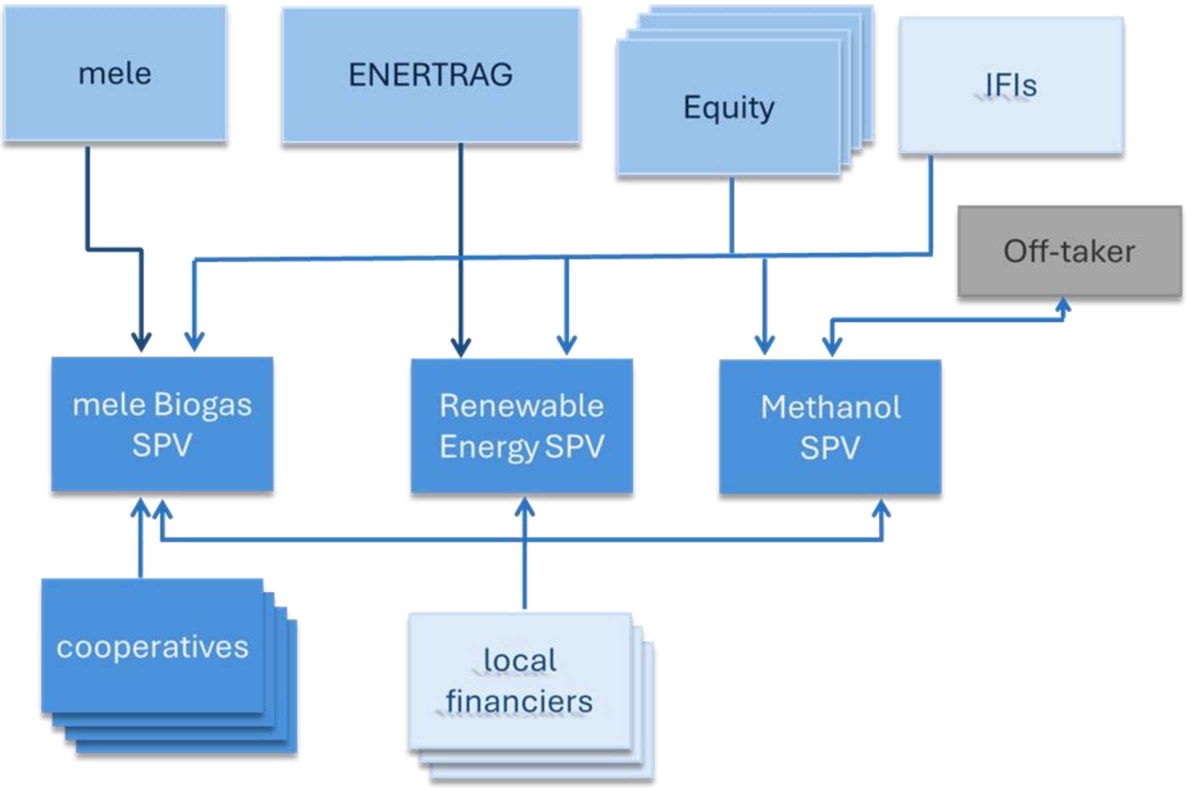

Figure 7-6 Structure of finance for biogas-to-methanol project

As an alternative, a holding company holding the shares of the SPVs could be established as an additional layer if useful for channeling the loan funds, as shown in the graph below.

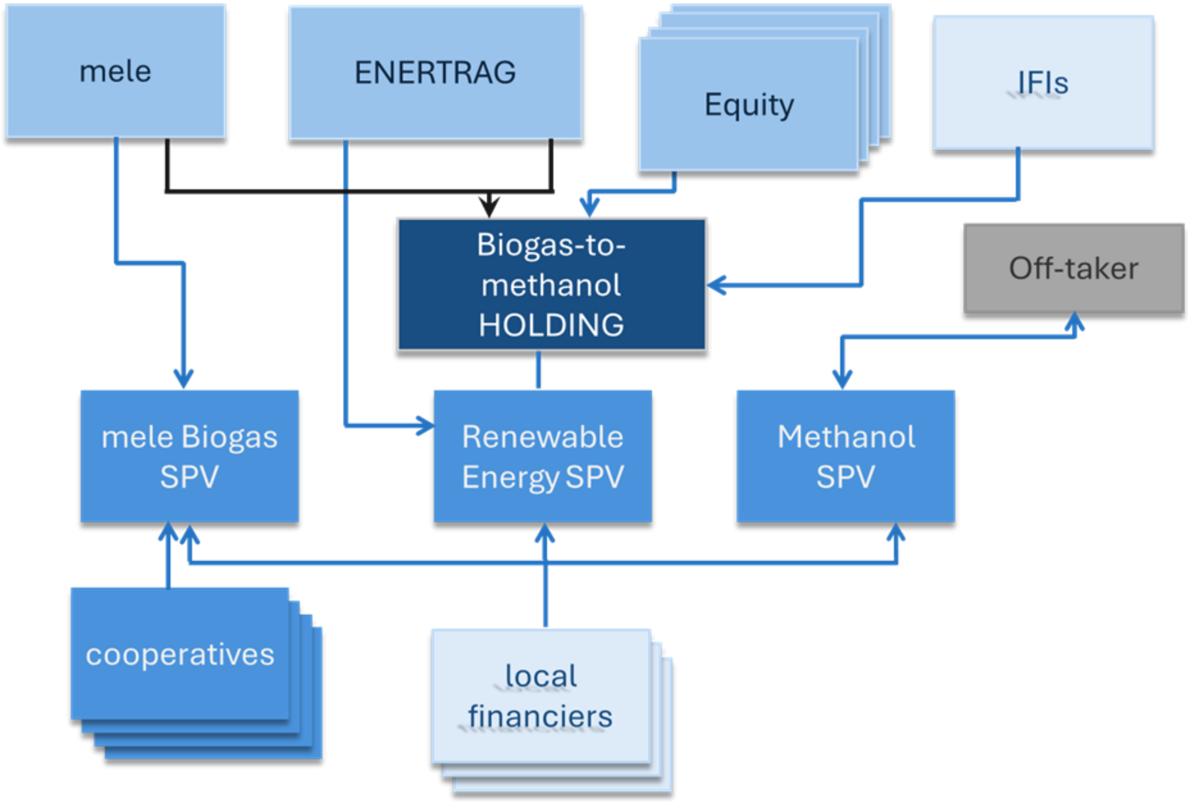

Figure 7-7 Holding structure of project finance for Biogas-to-Methanol project

7.7.1.1 Potential Investors for the SPVs

Potential investors for the Biogas SPV would be mele and possibly the local cooperatives. However, more investors are needed and should be approached.

Potential investors for the renewable energy plants could be local as well as international energy companies. Companies with adequate experience and financial strength should be approached, with ENERTRAG becoming one investor and coordinating that process.

The same applies for investors in the chemical (methanol) plant. A contact with ThyssenKrupp has been established.

7.7.1.2 Potential off-takers of the final product

The off-takers of the final product (methanol / syncrude) have to be engaged in the project on a long-term basis with fixed prices (indexed). They must be reputable companies with a long-term interest and sufficient financial strength. Evonik could be one candidate. More companies, both internationally and in Brazil should be approached.

7.7.2 The contractual structure of the project

The contractual structure of the project will encompass the following main sets of agreements (Project Agreements):

(i) Shareholders and Sponsors Support Agreement

(ii) Offtake Agreements

(iii) Equipment Supply Agreements

(iv) EPC Contracts (and sub-contracts)

(v) Operation and Maintenance Contracts

(vi) Infrastructure related agreements (e.g. grid connection agreement, water supply agreement, transport agreements)

(vii) Permissions by local authorities

(viii) Insurance Agreements.

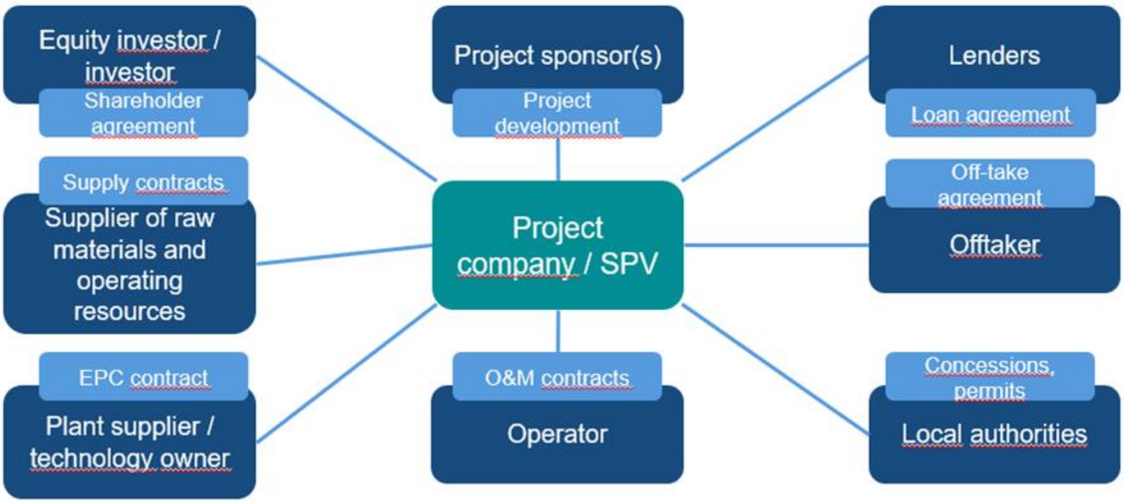

Figure 7-8 Main contracts for project finance

i) Thinking the payment streams from the backend the Methanol SPV will sell Methanol to one or more international off-takers. The Offtake Agreements will be denominated in Euro. In case the SPV will sell also to local off-takers the currency of the contract still has to be determined. The Methanol SPV will buy its inputs from the Renewable Energy SPV (electricity) as well as from the Biogas SPV (biogas). It is recommended that the currency of the contracts should be partly in Euro to the extent Renewable Energy SPV and the Biogas SPV need foreign currency to repay their foreign currency loans by which they have financed their capital expenditures and partly in Real so that the SPVs can match their cost in Real (mainly OPEX).

ii) Equipment Supply Agreements should be concluded either directly between the SPVs and the equipment suppliers or as subcontracts to the EPC Contracts. This will be determined i.a. by the requirements of any export credit insurers, if applicable.

iii) For the erection of each of the plants the SPVs will conclude EPC (Engineering – Procurement – Construction) contracts with qualified companies. The main terms of such contracts should be (a) turnkey,

(b) fixed price, and (c) date certain. EPC contractors should provide the usual performance guarantees. The EPC contracts should contain market standard clauses with regard to e.g. variations, defects liability, intellectual property, force majeure and termination.

iv) Operation and Maintenance (O&M) contracts: The SPVs will hire O&M companies for operating and maintaining the plants. In the case of the Biogas plant the O&M companies would most probably be Mele whereas ENERTRAG would be the O&M candidate for the renewable energy plants.

7.7.3 Lenders for the project

Given the size of the project only a bigger consortium of lenders will be able to bring up the necessary funds. Such a consortium should consist of both international and local lenders as follows:

(i) International Lenders:

- (a) Multilateral Financiers (IFIs) (e.g. IFC, IDB, EIB)
- (b) Commercial banks with specialization on project and export finance
- (c) Bilateral Development Finance Institutions (KfW, DEG),
- (d) Funds

(ii) Local Lenders:

- (a) Development Finance Institutions (e.g. BNDES)
- (b) Commercial banks with experience in project finance

(See fig.1 and Section 3).

7.7.4 The characteristics of lending & export credit guarantees

Main features of lending will be:

(i) long-term
(ii) grace period during construction and ramp-up phase
(iii) sufficient tail (period between last repayment date and project duration)
(iv) repayment profile in line with project cash flows
(v) interest rate: variable interest rate basis (e.g. Euribor) plus margin
(vi) margin reflecting project risk
(vii) interest rate hedging against interest rate fluctuations
(viii) multi-currency, if required.

7.7.5 Integration of export finance

If feasible, export credits could be integrated into the project finance scheme in order to make use of governmental export credit insurance programs, such as Euler Hermes in case of German exports. The regulations of the OECD consensus especially with regard to loan life have to be taken into account. This should probably also include the insurance of debt to the SPV by UFK (see section 6 of this report:

(i) Apart from ECA cover also other risk instruments should be integrated if useful, thus mitigating both political and commercial risk of lending This also includes the i.
(ii) In that sense other financing parties may be

- Export Credit Agencies (export finance could possibly be integrated into the financing structure)

- Investment Guarantee Providers (e.g. MIGA, PwC on behalf of German Government)
- Private Risk Insurers
- Hedge Providers.

7.7.6 Financing agreements

The set of Financing Agreements will encompass:

(i) Loan Agreements (Common Terms Agreement and Separate Loan Agreements for each lender)

(ii) Project related security package (especially security over

- (a) shares and project assets
- (b) bank accounts
- (c) project agreements
- (d) insurance agreements; negative pledge; direct agreements)

(iii) Risk insurance package (export credit guarantees, investment guarantees, private risk insurances)

(iv) Hedging Agreements.

One of the major challenges in structuring the project and its financing will be the timing of the various sub-projects. It must be made sure that once a sub-project has reached commercial completion and the repayment of the loans is about to start cash flows will be available for that.

7.7.7 The road to financial closing

When approaching potential lenders, Project developers (NIRAS, mele, ENERTRAG) will present them a detailed information package (see 0 for a checklist of information / documents). For preparing that various advisors need to be hired, in particular:

Financial advisor
Technical advisor
Environmental and social advisor
Market advisor
Legal advisor
Insurance advisor
Tax advisor and
Financial modeller.

There will separate groups of advisors on both the Investors' and Lenders' side in order to avoid conflicts of interest. Usually, the financial advisor takes the advisory lead role.

Lenders will carry out a due diligence process of the proposed financing. As lenders will rely solely on the cash flow of the project / the sub-projects the off-take agreement and the management to the operational risks are especially important. As lenders think in downside scenarios, they will carry out a detailed assessment risks mentioned in section 3.4 above.

During the entire process the financial model is of key importance, as it serves the investors for calculating the profitability of their engagement as well as the lenders as an instrument for assessing their potential risks and for optimizing the structure of the project finance. For that the model needs to show i.a. financial covenants, sensitivities, and risk mitigation instruments, e.g. debt service reserve account.

The process of financing such a project can thus be divided into the following phases:

1) Preparation of the project by the project sponsors until the banks are approached
2) Preliminary examination of the project by banks, financing offer (term sheet)
3) Acceptance of the financing offer, detailed project review, structuring of financing, conclusion of all contracts
4) Establishment of readiness for payment, start of construction, then start of operations
5) Ongoing monitoring of the project until the end of the financing term or the project term.

From a banks point of view the project financing process can be described as illustrated below and has also been spelled out in 0.

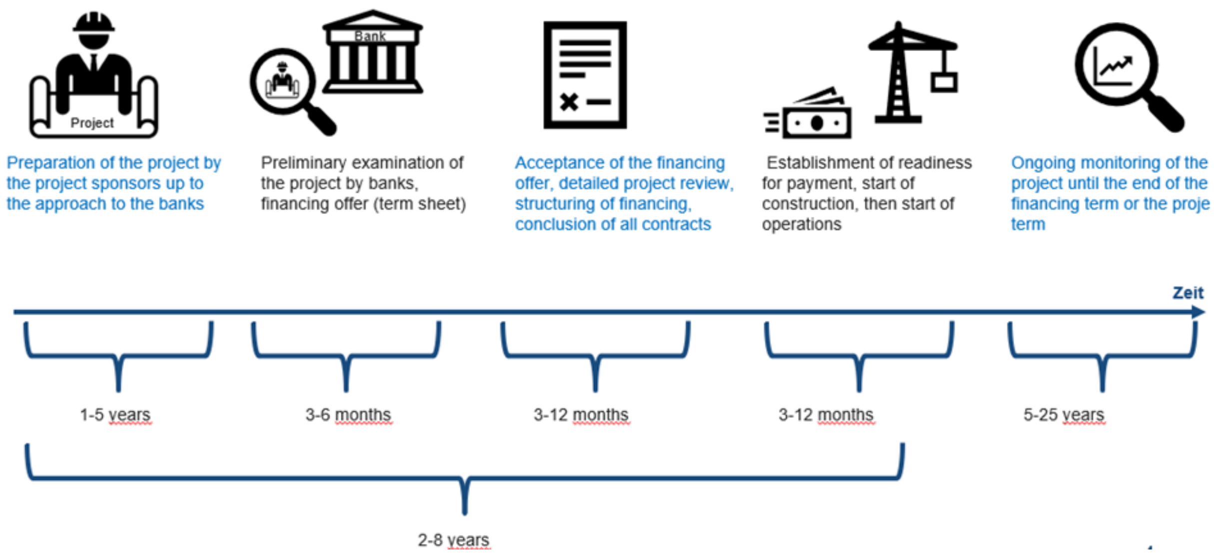

Figure 7-9 Project finance process

Documentation Requirements which financiers usually have are summarized in 0.

The project teaser is supposed to address all investors and possibly also off takers. Shares of local and international finance shall be developed in close cooperation with the project owner(s).

Financial modeling is another important deliverable for the banks to assess the project. The requirements for the financial model are presented in 0.

7.8 Conclusion and Next Steps

The Biogas-to-Methanol is a large (ca, € 1.5 billion) and complex investment project which requires a very international project finance to be concluded.

The current prefeasibility study needs to be followed up by an intensive multi million project feasibility and development phase.

allows to engage int further discussions with all types of financiers but also with off takers international financing institutions (IFIs) such as the EIB have a political mandate to finance the hydrogen ramp-up and are very interested in the project.

Two main issues appear to be important as next steps.

Private equity investors need to be acquired for the equity portion of the SPV and project finance but also for the financing of the project development phase.

Public funding / subsidies have in parallel to be acquired for the financing of the further project development.

The road towards the signature of an off-take agreement needs to be walked by further optimizing the logistics e.g. regarding the storage for fluctuation availability of electricity and ships taking off the methanol.

7.9 WHAT IS THE PROJECT SCOPE AND OBJECTIVE?

This summary explains the major findings of the pre-feasibility study for the production of green e methanol and green hydrogen from abundant Biogas resources in Paraná in Brazil

Within the H2Uppp project a feasibility assessment has been carried out on the possibility of producing green fuels in the Western Paraná region based on green hydrogen, produced from renewable energy (RE) sources, and biogenic carbon from animal and agricultural wastes. Different synthetic fuels have been considered and many technologies for biogas utilization and green fuels production have been reviewed. The result of this analysis is an initial process design flow diagram of a methanol plant that outlines, as first iteration, the process layout, the main components of the plant and it is used to perform a class 5/4 cost analysis as part of the business model evaluation.

7.9.1 Financing of the pre-feasability study

The German Society for International Cooperation (GIZ) is responsible for the implementation of the H2Uppp program which financed the feasibility to ME-LE GmbH in Germany and its partners. GIZ invited and awarded this contract to NIRAS International Consulting to manage the team of experts in Brazil, Denmark, Chile and Belgium to conduct the FEL-I Engineering assessment for the production of e-methanol from Biogas and Green Hydrogen, advise on hydrogen and e-fuels export's certification, advised and training on the requirements to guarantee a proper animal welfare for the cooperatives producing Biogas, advised in detail the legal, regulatory and environmental licensing that apply to this project in particular and assessed the economic viability and financial modelling and international financial advisory to prepare the project documentation as requested by international donors and investors.

7.9.2 About NIRAS

NIRAS and NIRAS International Consulting is an advisory, development and engineering consulting company with over 3500 employees worldwide, present globally in over 65 offices across all continents. NIRAS clients portfolio includes Development Donors such as KFW, GIZ, DANIDA, SIDA, The European Comission, the World Bank, and numerous private companies. NIRAS conducts over 400 projects per year with a turnover of 508,8 millions of Euros in 2023. NIRAS field of expertise include international development cooperation, green fuels and green energy transitions (greensition programme), renewable energy, GIS and special analysis, automation, energy efficiency in particular for the food and beverage industries worldwide.

7.10 Description of the project: GREENFUELS PARANA (GFP)

7.10.1.1 Initial Situation

The Western Paraná region of Brazil is a hotspot for animal production, particularly pig and poultry production. The resulting manure causes significant environmental problems because disposal is not guaranteed. Manure seeps into the soil or flows into rivers; large amounts of nitrous oxide and methane are emitted when the manure is stored in open lagoons.

The Green Fuels Paraná project includes the utilization of pig manure, chicken manure and other residues from agricultural production in the Western Paraná region. In the first step, biogas and fertilizer are produced from the digestate.

Tabela 7-2

Production Key Figures	
Fattening pigs, sows, piglets	4,012,000 pigs ()
Poultry production	63,130,000 pieces of poultry
Dairy Production	26,455 dairy cows
Manure per year	13,000,000 cubic meters
Biomethane determined potential	30,000 Nm³/h
CO2eq avoided from Biogas	1,100,000 million t per year
CO2 avoided through separated CO2 (BECCU)	0,28 million t per year

Source: own elaboration

7.10.1.2 Location of the Project

The project is a central part of the Government of Paraná's State Sustainability Program for Western Paraná (Paraná Oeste Sustentavel). The location is shown below

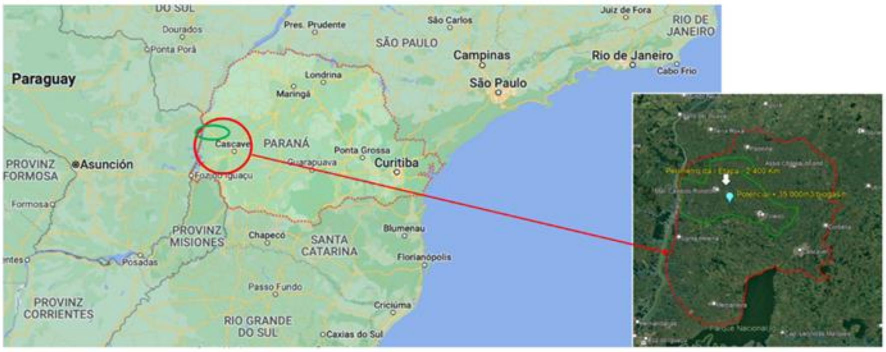

Figure 7-10 Project Location

7.10.1.3 Goal of the project and fundamental assumptions

Within the H2Uppp project a feasibility assessment has been carried out on the possibility of producing green fuels in the Western Paraná region based on green hydrogen, produced from renewable energy (RE) sources, and biogenic carbon from animal and agricultural wastes. These agricultural residues are used to produce biogas, with the objective of ensuring that the residues are transported to the locations of the respective biogas plants in the most environmentally friendly way possible while improving animal welfare practices by farms and cooperatives in the region.

7.10.1.4 The feasibility evaluation from 2023-2024

The feasibility assessment considers different synthetic fuels and many technologies for biogas utilization and green fuels production have been reviewed. The result of this analysis is an initial process design flow diagram of a methanol plant that outlines, as first iteration, the process layout, the main components of the plant and it is used to perform a class 5/4 cost analysis as part of the business model evaluation.

7.10.1.5 Required expansion of biogas production – important remarks

The design of the green fuels refinery assumes a total biogas capacity of 50,000 Nm^3/h or the equivalent of a 30,000 Nm^3/h of biomethane. These amounts mean that an expansion of the current biogas production situation is necessary. For this purpose, additional cooperatives of producers from the region are being founded and integrated. More than 2.500 producers are involved. The company and the cooperatives plan to do it in partial steps.

A first biogas plant with a planned production of around 1,300 Nm^3/h of biogas has already been developed and approved. A total of up to 40 biogas plants are to be built until?. The biogas produced is processed into biomethane and its CO2 is subsequently separated. Which advantages and risks are involved in this expansion?

Pipeline system construction and financing should be mentioned here
Financing structure of the expansion of the 21 plants should be mentioned here shortly and provide more information in annex.

The production concept is shown in the following figure.

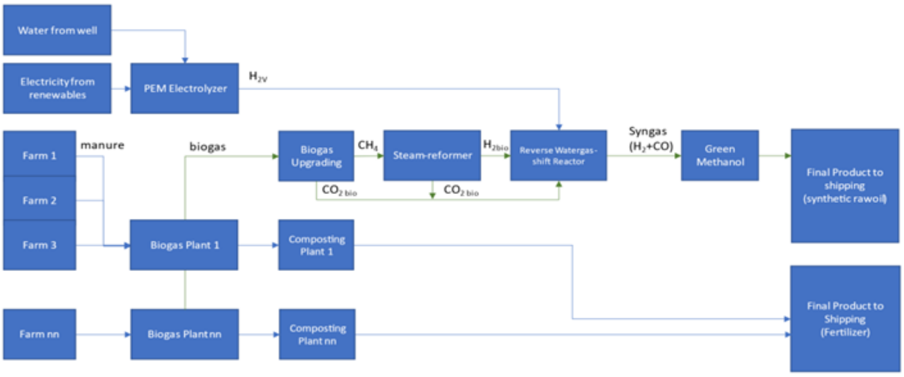

Figure 7-11 Production Concept

The liquid pig manure is fed to the biogas plant via a pipeline network connected to the respective fattening plants, so that the manure can be permanently fed into the gas-tight interim storage facility at the biogas plant using pumps without the need for vehicle transport. The other residues are planned to be transported by trucks as the transport routes are short, as all of the residues described for a microcenter occur in an area of only around 100 square kilometers. The companies with the shortest routes are also included for the location of the respective biogas plants. In order to generate the intended total potential, a total of 21 biogas plants must be built in two municipalities Toledo and Nova Santa Rosa) alone.

7.10.1.6 The concept of a green fuels biorefinery for the Toledo region – important remarks

The process design phase aimed to compare the feasibility of producing two different green fuels, syncrude/SAF and methanol. This phase has been aided by process modelling software, implementing well-established kinetic models and fully detailed equipment modelling, to achieve higher prediction accuracy.

The design of the green fuels refinery assumes a total biogas capacity of 50,000 Nm^3/h or the equivalent of a 30,000 Nm^3/h to be collected by all the different cooperatives and biomethane producers. This involves a larger coordination effort in the region under the leadership of Me-Le and the green fuel producer.

The engineering process design and concept for the e-methanol refinery developed at this stage underlies an important assumption, as required by the H2Uppp program, which is selecting process exclusively from proven technologies. Therefore, technologies such as biogas direct reforming have been reviewed and deemed too immature for this project, despite being theoretically more efficient. This reduces several technological risks by adopting higher TRL levels, with important impact for the business model and further for project financing.

Another key process design assumptions refers to the perspective of CO2 use maximization from the biogas stream to produce green fuels, given that biogas contains large amounts of CO2 (35%-40% in molar fraction). For this reason, possible reforming technologies such as ATR and POX are not included in the design proposition as they would produce more CO2. The use of green H2 is directly dependent from the CO2 utilization degree.

The economic evaluation of this project is based on CAPEX and OPEX indicators that has been carried out using the factorial cost methodology; a high-level cost estimation and business case comparison has been carried out between syncrude and methanol routes, together with a detailed factorial cost estimation for the methanol plant case. Out of this technical and economic feasibility evaluation are left logistic organization aspects involving transport of biomass to the plant site and transport of the green fuel product to a potential off-taker location. LCA is also out of scope for this project.

7.10.1.7 The production of Biogas in Toledo, Paraná

The availability of carbon sources (animal manure and residues from agricultural production) is supplied by over 2.500 producers, in particular animal fattening farms, slaughterhouses, cassava processors, etc. In total, around 13.5 million cubic meters of substrates are available per year, of which around 1.5 million cubic meters of higher-quality substrates (poultry manure, residues of slaughtering and cassava-production) are fed into the digestors and the rest, around 12 million cubic meters of pig manure, is fermented in lagoon systems.

In total, the plants produce around 1.2 million Nm^3 of biogas per day or around 50,000 Nm^3/h. Due to the high methane content of approx. 59%, this results in a methane yield of around 30,000 Nm^3/h. The concept of biogas production is identical for every plant, technologically and capacitively. It corresponds to the technical concept of the mele group, as it is also implemented in Germany:

Figure 7-12 Biogas plants built in different parts

The first such system with the concept of pipe connection to the manure suppliers has been developed and has a building permit. The facility is being built in Toledo, Rocio district and has the site plan attached below.

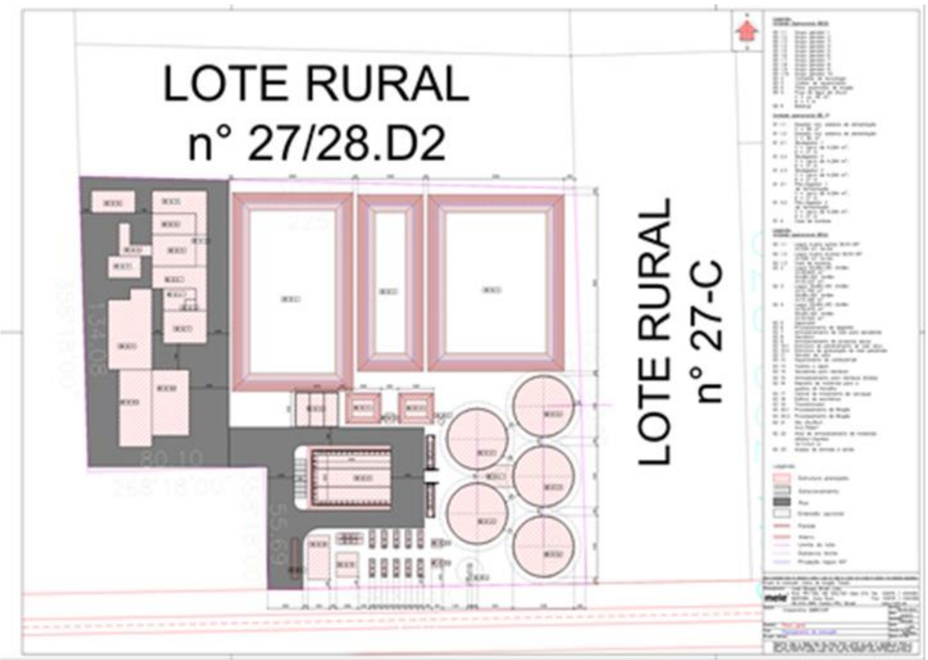

Figure 7-13 Site Plan

Construction is scheduled to begin in April 2024 after construction preparations have been completed. The pig manure is fermented in the lagoons and the biogas is fed into the biogas pipelines to the production site. The digestate is processed into natural fertilizer in the neighboring composting plant. The remaining substrates with significantly higher dry substances are fermented in the 5 reinforced concrete containers. The digestate also goes into the composting plant.

The biogas produced is temporarily stored in the gas-tight double-membrane roofs of the containers and lagoons and fed into the biogas pipeline network to the central production facility.

Figure 7-14 Overall location plan concept

The overall location planning concept has been agreed with all communities involved. The following figure shows the current status of the concept. The area outlined in yellow is the location of the PV and wind turbines. The central production location is also located there.

7.10.1.8 Production of biogenic hydrogen

The biogas produced by the 40 biogas plants is pumped via a pipeline system to a central production site and is continuously processed there into biomethane. The processing/purification takes place via a membrane system, which processes the biomethane to largely natural gas quality. the CO2 is separated and fed into the further production process. The biomethane (CH4) is broken down into carbon and biogenic hydrogen using a steam reforming process.

7.10.1.9 Biogas reforming – technologies identification

The use of biogas for green fuel production poses some technology challenges, especially when it is required to maximize the CO2 utilization. According to state of the art technologies with high maturity levels, green fuels are produced from syngas, a mixture of H2, CO and CO2, which needs to have specific composition characteristics to efficiently be used in the green fuel synthesis unit. Biogas composition is typically not ideal to achieve the right composition. For this reason, and assuming that the green fuel process plant is downstream of the biogas upgrading unit, it is found that a post-reforming technique could offer an efficient route to produce syngas with correct composition for green fuel downstream production. CO2 from biogas is partially separated and re-injected in a later shift reactor, where reverse water gas shift reaction happens. An example of this process layout is proposed below. This process is tailored to produce syngas with lower H2/CO ratio composition which is ideal for the downstream processes such as methanol reactor or Fischer-Tropsch reactor.

The advantages of this post-reforming solution regard the lower risk of carbon deposition and reduce amount of water necessary in the reforming reaction together with a higher yield of CO2 conversion, with respect to conventional single-step steam reforming.

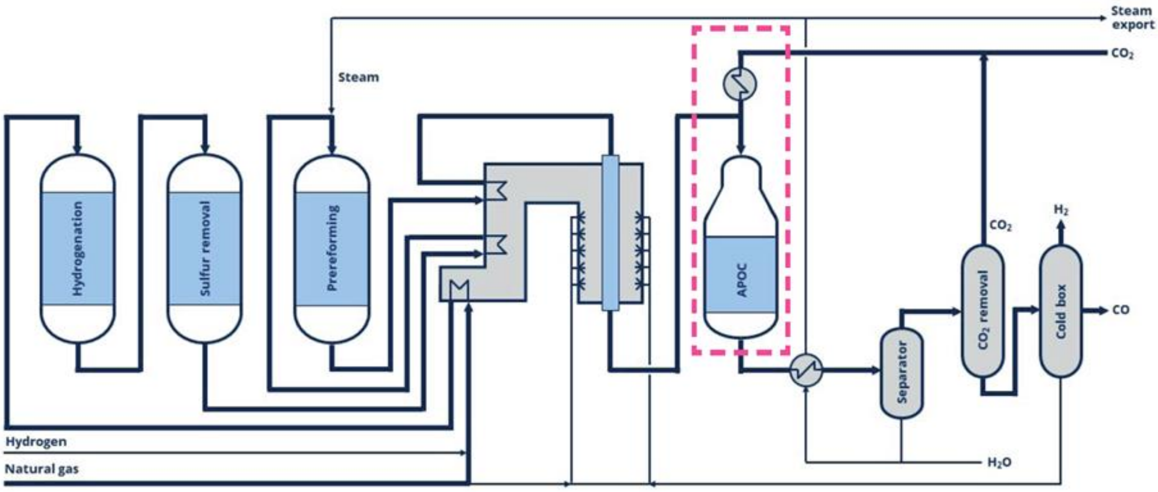

Figure 7-15 Technology identification for biogas reforming

7.10.1.10 Process Design – Green Methanol

The same post-reforming process scheme, to produce syngas, has been employed in the different plant designs, thus, a comparison between a syncrude/SAF-producing plant (two slightly different layouts) and a methanol-producing plant has been drawn. The focus of this teaser is however on the production of green methanol as shown below.

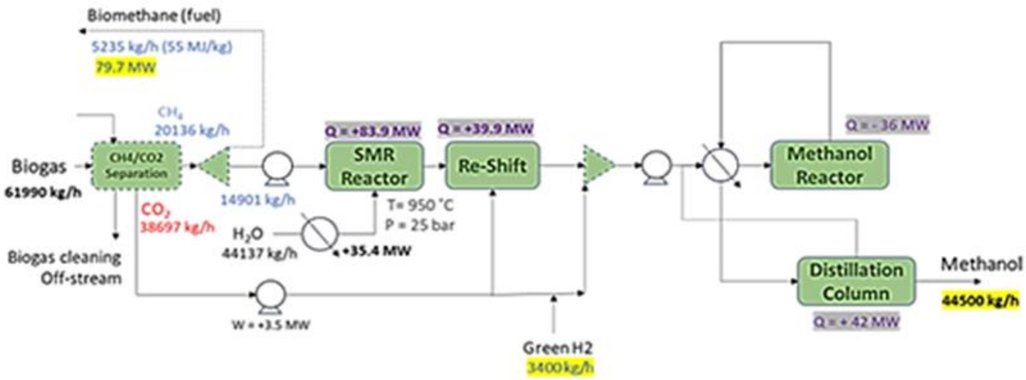

Figure 7-16 Process design for Green Methanol

Tabela 7-3

Summary Green Methanol	
Product output	44500 kg/h
Green H2 requirements	3400 kg/h
Power requirements	250 MW

Electrolyzer	205 MW
Compressors	45 MW
Estimated water requirements	237 m^3/h

7.10.1.11 Production of green hydrogen:

Renewable energy is produced at already defined locations. A wind farm and a solar park with an output of 250 MW el. will be built. The electricity generated is used to produce green hydrogen via a direct connection to the central production site. The electrolysis plant has a capacity of 160 MW el.. The green hydrogen also goes directly into the production process for the green methanol. Extensive studies have determined sufficient water resources for the electrolysis process.

7.10.1.12 Production of green methanol:

The plant to produce green methanol will also be built directly on the central production site and will have a total capacity of 400,000 tons per year. The expected availability is 350,000 tons/year.

7.10.1.13 Operations:

The entire system is technically supported and operated by the partners over the long term. Extensive training programs are carried out. The availability of workers in the region is above average, as there are a number of universities in Parana that offer courses in renewable energy, biogas, hydrogen, etc. offer. A few years ago, the Mele Group itself carried out a large training project together with SENAI and the Federal Ministry of Education for biogas plant operation and management. In total, up to 1,000 new jobs are expected in the entire project.

7.10.1.14 Project development plan:

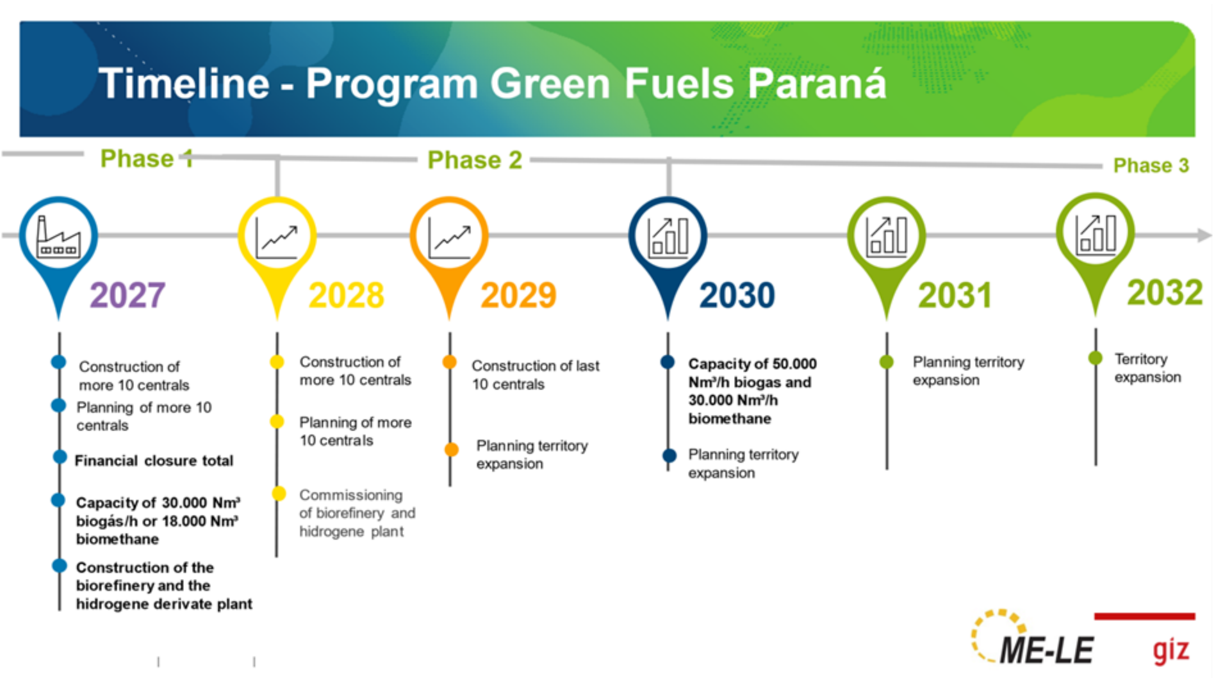

Figure 7-17 Timeline of the Green Fuels Paraná Program

The further project development envisages that the biogas plants will be built in the first phase with 20 plants by 2027. This also applies to the wind and solar park and the production site, so that around 70% of methanol production has already been achieved. The second phase with full production is scheduled for 2030. The total production of green methanol will then be 250.000 tons/year from 2027 and 350.000 tons/year from 2030.

7.10.1.15 Logistics and transport:

In Brazil, transport is generally carried out by truck. There are only a few rail connections. These specialize exclusively in freight transport.

There is a continuous rail connection in the region from the town of Cascavel, approx. 60 km south of the production site, to the Atlantic port of Paranagua. (Ferrooeste). The line is to be extended northwards in the next few years and passes close to the production site. The exact route has not yet been determined. The construction of a siding would then be conceivable.

Since the methanol is liquid, it must first be transported to the freight station in tankers and then pumped into tank cars. The methanol is then pumped into a ship in the port. If marketing takes place in Brazil, the transport costs must be determined alternatively, depending on the destination.

The costs requested from freight forwarders are 40 euros/ton for truck transport exclusively with tankers to the port of Paranagua. Using partial transport by train results in a total saving of 25%, i.e. 30 euros/ ton.

7.10.1.16 Contract concept between project company and cooperatives

To implement the biogas projects, the producers and suppliers of the substrates set up cooperatives:

There are currently 4 cooperatives that will be involved in the planned projects.

Ambicoop, responsible for the projects in Toledo

Coopersan, responsible for the projects in Nova Santa Rosa

Cooperpont, responsible for the projects in Quatro Pontes

Coogesmar responsible for the projects in Marechel Candido Rondon

Other cooperatives are in the founding phase.

In principle, the cooperatives will manage the business on their own account. Technically they are managed by the mele group. The biogas plants and ancillary facilities are financed by the project company. A leasing-like contract for each biogas plant is concluded between the cooperatives and the project company, with a term of 15 years. During this period, the investment, additional financing costs and interest are repaid by the cooperative in monthly installments. After full repayment, ownership of the assets passes to the cooperative.

In return, the respective cooperative will conclude a supply contract for the biogas with a term of at least 35 years, with extension options. The initial price for one kwh is 0.048 euroct, with a current exchange rate of 5.25 real/euro = 25.2 centavos/kwh. Further details are then regulated by the delivery contract.

7.10.1.17 Project financing

7.10.1.17.1 Capex and Opex Analysis for Green Methanol

The initial part of the biogas potential studies, the structuring of the legal model, the structuring of the first four rural sanitation and renewable energy generation cooperatives, the executive projects for the first Rocio plant, the acquisition of the first two areas of land for the implementation of the first plants, these investments totalling approximately 3 million euros, were financed by the companies Me Le Biogás and Greentrx. The feasibility studies for the processes after this initial phase are being carried out in close cooperation with GIZ through a PPP, in which Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH contributed 478,400 euros through the H2Uppp Programme.

The additional costs of Rocio's First Biodigestion Plant, the first of 45 planned, with design and other fees for finalising and approving projects are being borne by Me Le Biogás Brasil and H2V - the companies contracted to manage the construction and operation of the first plant.

The machinery, equipment and civil works for the first plant will be financed by the BRDE Bank with funds from the Climate Fund. Considering the nature of the project, BRDE is interested in studying the viability of the carbon credit instrument as part of the guarantees. To finance the development of the executive projects and other complementary studies for the implementation of the other 44 plants, composting plants and fertiliser industries, the necessary resources are shown in the table below.

Table 7-4 Calculated operation in EUR for Green Methanol

Calculated Operation in EURO	%	Total EURO
Total CAPEX	100%	548.048.584,20
Expected Tax Exemption	14,77%	80.941.779,08
Expected CAPEX after tax exemption		467.106.805,12
Financing operation, 15-year grace period capital repayment		
Own Capital	1,00%	4.671.068,05

7.10.1.17.2 Capex and Opex Analysis for the green methanol plant

In the context of the analyses for biomethanol production (Scenario C), three new scenarios were examined based on different sets of input data, designated respectively by the data sources: NIRAS, MeLe and Uncertainty 50%. Below are the results of the the data assumed for the construction of the biorefinery to produce biomethanol. The results show that all the scenarios are viable from a technical, economic and financial point of view. However, in order to adopt a conservative stance and choose the most likely option, we opted to finalize the results with the alternative based on the data shown below. This scenario shows attractive indicators in terms of Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period.

The reasons for these results, compared to the scenarios for Syncrude/SAF production, lie in the lower complexity of the construction and operation processes, as well as the market price being lower than the levelized price. The simplicity of the technological processes, the greater production capacity and the current market price make this option the most viable of those considered.

The analyses and studies carried out covered all the processes involved, from the production of biogas and green hydrogen to obtaining the final fuels. In addition, the essential utilities for the processes, such as energy and water, were duly considered. To meet the energy demand of the processes, the forecasts established by the technological studies, which include photovoltaic solar energy and wind energy, were taken into account.

It is important to note that in our analyses and studies, we have taken into account all applicable taxes, as well as exempting incentives of various kinds generally granted to projects in the biogas, green hydrogen and biofuels segments. As a result, we have presented adverse and conservative scenarios, providing investors with a wider margin of safety in their investments. It is certain that these projects will have substantial benefits and incentives granted at municipal, state and federal level, which will have an even more positive impact on the economic and financial viability of the ventures.

Tabela 7-5

Green METHANOL		Scenario C.
CAPEX Total (**Millions €**)	Total CAPEX – TCI (modules, engineering, BoP, civil & contingency)	€ 1,578
Total OPEX (**Millions €**)	Total OPEX – (plant operations,utilities maintenance, depreciation and interests)	€ 312
Production (Ton/h)		40.0
Numbers of Hours		8,117
Production (Ton / year)		324,680
Euro / Ton		€ 1,500.00
Annual Revenue (A) **(Millions €)**		**€ 487.02**
Biogas Plant CAPEX		MM€ 530 / 15 anos
Annual installment (B) **(Millions €)**		€ 35.33
(A)+(B)		
Year 2 to Year 16 **(Millions €)**		€ 522.4
Year 17 to Year 20 **(Millions €)**		€ 487.0

Capital sources		
Equity (E)	30.0%	€ 473.5
Third Party Capital (D)	70.0%	€ 1,104.9
Income tax (zero % due to applied incentives)	34.0%	

Inflation	2.0%	
Cost of internally sourced capital (Ke)	10%	
Cost of capital from external sources (Kd)	6%	
(50% development bank + 50% private bank)		

WACC		4.8%
$WACC = [Ke\left(\frac{E}{D+E}\right) + Kd\,(\frac{D}{D+E})]*(1\text{-}T)$		

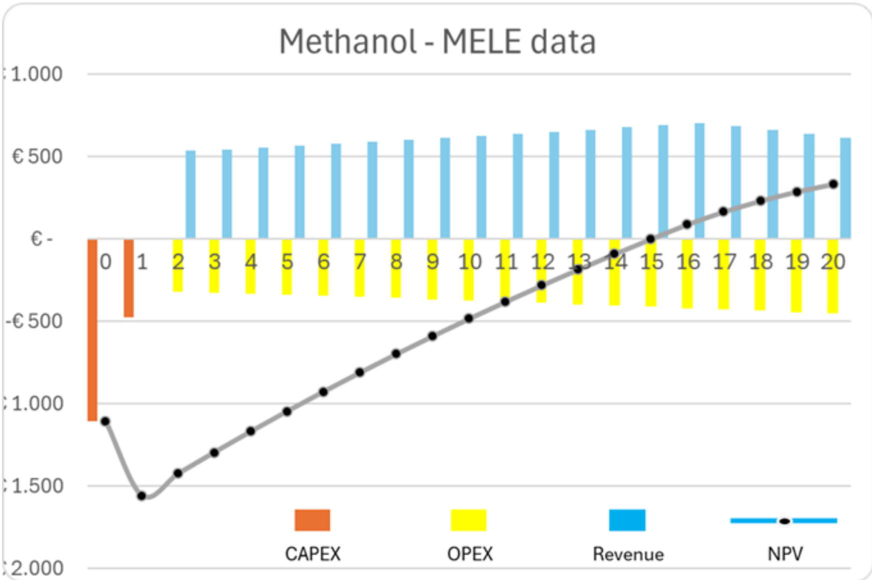

Figure 7-18 Complete Financial Modelling results for Green Methanol

Impact of renewable energy plant is significant on the levelized cost of the product. Renewable energy plant is sized to cover the majority of the green hydrogen plant power requirements, alone above 200 MW for scenario C and B, thus resulting in a significant increase in the capital expenditure needed. This fact together with relatively high interest rate and discount rate makes the capital expenditure weighs heavily on the levelized cost. It is therefore suggested in the next phase of more detailed process design to decide for an electrolyzer and renewable plant size and design the chemical process to best fit that scenario.

7.10.1.18 Technical feasibility of methanol VS syncrude/SAF

The technical feasibility of each process scenario layout was evaluated and it is found that with an optimized process design both green fuel production routes (specifically syncrude/SAF route A and methanol route C) can be economically feasible. Each process configuration has its own unique advantages and disadvantages in terms of cost, yield, hydrogen requirements, and water utilization, making them suitable for specific local conditions and requirements. From the technical complexity point of view, it is observed that a methanol plant offers advantages and a higher degree of flexibility for future investments and changes.

7.10.1.19 Commercial feasibility of methanol VS syncrude/SAF

A simplified economic comparison has been performed estimating Capex and Opex to compare the different scenarios. Considering the final levelized cost of the products and comparing that to estimated methanol and SAF price, respectively in the range of 700-1600 $/ton for methanol and 1400-2400 $/ton for SAF, it is found that both methanol plant scenario C and syncrude/SAF scenario A could potentially result in positive business cases, depending on the actual market price value. It is worth to mention that the levelized cost of methanol is more dependent on the electricity price or the size of renewable plant. The reason for this stems from the initial working hypothesis of maximizing the use of CO2 contained in the biogas and consequently maximizing the amount of green H2 needed. In detail studies upon the most appropriate amount of CO2, and thus electrolysis plant size, have not been conducted within the scope of this project. Such optimization studies are going to be necessary in a future FEL 2 or FEL 3 project to minimize the levelized cost of the product.

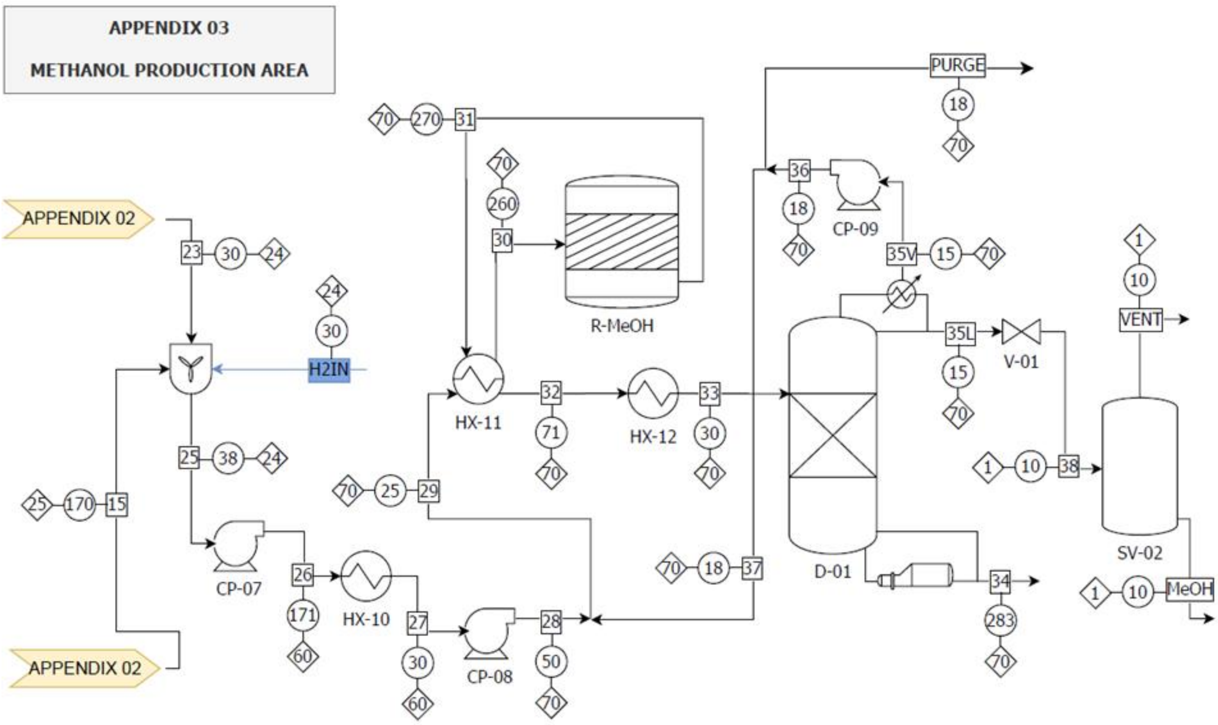

Figure 7-19 Methanol production area

The more detailed process design results in a diminished methanol product output of 33150 kg/h, which has an immediate impact on the levelized cost. The following table summarizes the main characteristics.

Tabela 7-6

Main Characteristics of Detailed Methanol Plant	
Methanol Product Output (kg/h)	33150
Levelized Cost of MeOH (with RE plant) ($/ton)	1510
Levelized Cost of MeOH (with PPA only) ($/ton)	1246

Methanol plant productivity needs to be optimized together with the sizing of the electrolysis plant in order to make a feasibile economic case.

7.10.1.20 Renewable Plant and Electrical requirements Analysis

Facilities could be powered by long-term RE PPAs in an indirect grid connection scheme with lower CAPEX compared to deploying new RE plants. However, in scenarios where green-H2 is incorporated into the product, the green fuel might be partially classified as RFNBO. Even in this high renewability grid area (>90% RE), if meeting this certification is desired, it's recommended to finance new RE plants based on local and/or remote self-production grid-tied scheme assisted by smart metering.

7.11 Final considerations

The Biogas-to-Methanol is a large (ca, € 1.5 billion) and complex investment project which requires a very international project finance to be concluded. The current prefeasibility study needs to be followed up by an intensive multi million project feasibility and development phase, allowing to engage int further discussions with all types of financiers but also with off takers international financing institutions (IFIs) such as the EIB have a political mandate to finance the hydrogen ramp-up and are very interested in the project.

Two main issues appear to be important as next steps.

- Private equity investors need to be acquired for the equity portion of the SPV and project finance but also for the financing of the project development phase.
- Public funding / subsidies have in parallel to be acquired for the financing of the further project development.

The road towards the signature of an off-take agreement needs to be walked by further optimizing the logistics e.g. regarding the storage for fluctuation availability of electricity and ships taking off the methanol.

Based on the results of the analyses carried out for this economic and financial feasibility study of the projects in question, we can say that the 45 Biogas Plants Project are a viable and highly attractive investment in terms of financial return and environmental benefits.

The choice of the e-methanol production chain is technically less complex than that of Syncrude/SAF, which results in a reduction in the associated economic risks and provides greater flexibility. The studies show an attractive viability for this approach. The technological complexity and high capital investment associated with the level price of this biofuel make investment in the Syncrude/SAF plant significantly less attractive and with a high financial risk. Therefore, its economic viability is considered unfeasible.

The economic and financial feasibility analysis is uncertain due to the need to improve the details of the technologies used. Further refinement is therefore recommended as the studies progress.
It is important to note that the results presented reflect conservative scenarios, taking into account the rates and taxes applicable to a project of this nature. However, it is important to note that bioenergy projects, especially involving biogas, biomethane, green hydrogen and biofuels in general, are supported by exemptions and incentives that can make the project even more attractive.

It is important to note that the results presented reflect conservative scenarios, taking into account the rates and taxes applicable to a project of this nature. However, it is important to note that bioenergy projects, especially involving biogas, biomethane, green hydrogen and biofuels in general, are supported by exemptions and incentives that can make the project even more attractive.

We express a highly favorable opinion of this partnership of investors in the projects, highlighting that the project has the intrinsic support of public, private and academic institutions that make it of great importance for regional, state and national development towards sustainability. In addition, this initiative strengthens ties between Brazil and Germany, providing mutual benefits in environmental, economic and social terms for both countries, including positive impacts on local and global decarbonization.

ANNEXES – LEGAL ASPECTS

LEGAL REGULATORY REPORT ON THE FEDERAL PUBLIC POLICY FOR BIOGAS AND BIOFUELS

H2UPPP PROJECT - MELE BIOGAS GmbH

SIGLAS

ABIOGAS Brazilian Biogas Association
National Petroleum and Biofuels Agency
BNDES National Bank for Economic and Social Development
CBIO Credit for Decarbonisation of the National Biofuel Policy
CIBIO GAS International Renewable Energy Centre
CIMVC Interministerial Committee on Climate Change and Green Growth
CNPEC National Energy Policy Council
COFINS Contribution for Social Security Financing
COGENA - Cogeneration Industry Association
Greenhouse Gases
GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit
IBAMA Brazilian Institute for the Environment and Renewable Natural Resources
MCTI Ministry of Science, Technology and Innovation
Ministry of the Environment and Renewable Natural Resources
MME Ministry of Mines and Energy
ND Nationally Determined Contributions
Sustainable Development Goals
PIBB Programme to Encourage the Production and Use of Biogas and Biomethane and Associated Products
PIS/PASEP Social Integration Programme
PPP Public-Private Partnership
REID Special Incentive Scheme for Infrastructure Development
RENOVABI National Biofuels Policy
SISNAMA Sistema Nacional do Meio Ambiente
SNVS Sistema Nacional de Vigilância Sanitária (National Health Surveillance System)
SUASAS Unified Agricultural Health Care System
UNFCCC United Nations Framework Convention on Climate Change
UNICA Union of the Sugarcane Industry

1. BILL NO. 3.865/2021 - BIOGAS LEGAL FRAMEWORK

BILL NO. 3.865/2021 - BIOGAS LEGAL FRAMEWORK
(https://www.camara.leg.br/propostas-legislativas/2305317)

1.1. General considerations

Brazil is the country with the greatest biogas production potential in the world. This potential could reach 19 GW of installed capacity or 120 million m³/day of biomethane.

In this sense, incentives for biogas and biomethane are a short- and medium-term solution for increasing the supply of decarbonised, dispatchable and decentralised energy.

The Bill was drawn up with contributions from the Brazilian Biogas Association (ABiogás), the Cogeneration Industry Association (Cogen) and Unica (the Sugar Cane Industry Union) and technical support from the Ministry of Agriculture and Embrapa.

1.2. Initial Definitions and Environmental Licensing

> Art. 1 This law establishes the Incentive Programme for the Production and Use of Biogas, Biomethane and Associated Coproducts - PIBB and makes other provisions.
> Art. 2 The production of biogas, biomethane and associated co-products will be regulated by the Federal Government and may be carried out by rural producers, agro-industrial co-operatives, industries, companies or consortia of companies incorporated under Brazilian law, with headquarters and administration in the country.

Articles 1 and 2 of Bill No. 3.865/2021 state that the Incentive Programme for the Production and Use of Biogas, Biomethane and Associated Co-products - PIBB - will be set up and regulated by the Federal Government.

The Bill proposes the creation of a new legal regulatory framework for the sector, encouraging joint action by the Federal Government, through tax incentives to encourage investment in the production of biogas and biomethane, as well as the offer of credits with differentiated interest rates for the implementation of plants.

> Article 2 makes the Federal Government the inducer of the PIBB. The list of those who will be able to carry out biogas production activities also includes figures such as consortia, where companies unite around a common goal. The Bill specifies that companies must have their headquarters and management in Brazil, which means that foreign companies interested in the segment must have subsidiaries or partnerships set up in Brazil.

> Art. 3 The issue and renewal of licences for the installation and operation of enterprises producing biogas, biomethane and associated co-products for the purpose of generating energy will be the subject of specific regulations by the competent federal environmental body.

The environmental regularisation of biogas and biomethane concerns the control of environmental impacts and involves obtaining environmental licences, authorisations for the suppression of vegetation and the use of water resources, federal technical registration and other legal obligations with environmental agencies. The issuing of environmental licences takes into account environmental variables such as air, water and soil, and the combination of the potential of these variables determines the general polluting potential of the activity.

When addressing the competent federal environmental body for specific regulation of the PIBB, there will be a specific rule to be issued by IBAMA - the Brazilian Institute for the Environment and Renewable Natural Resources.

1.3. Definitions, principles and objectives

Articles 4 and 5 of Bill No. 3,865/2021 determine, respectively, the legal definition of the terms pertinent to the production of biogas and biomethane and the principles that guide the PIBB. There are four concepts set out in the text of Article 4:

> Art. 4 For the purposes and effects of this standard, the following definitions are adopted:
>
> I - Biogas: raw gas obtained from the biological decomposition of organic products or waste;
>
> II - Biomethane: gaseous biofuel consisting essentially of methane, derived from the purification of biogas;
>
> III - Digestate: anaerobic reactor effluent obtained from the biogas production process;
>
> IV - Energy use of biogas: use of biogas and/or biomethane and associated co-products to generate electrical, thermal and vehicular energy, as well as injection into natural gas lines.

Establishing these concepts in law follows the logic of eliminating any doubts among the participants in the production chain about the elements that make up the process. The inclusion of these concepts in the body of the law is the behaviour followed by all legal instruments that deal with energy models.
With regard to the principles set out in Article 5, the legislator's concern to make the implementation of a specific biogas policy feasible can be seen.

> Art. 5 The principles of this law are:
>
> I - a systemic vision of biomass and biodigestion management that considers environmental, economic, cultural, social and technological variables;
>
> II - the circular economy, through the optimisation of resources by circulating products, components and materials at the highest level of usefulness, both in the technical and biological cycles;
>
> III - eco-efficiency, through the supply, at competitive prices, of goods and services resulting from the exploitation, transport and commercialisation of biomass, biogas and biomethane; and
>
> IV - the recognition of biogas as an economic asset with social value, a generator of work and income and a promoter of local development;

By mentioning a systemic vision, circular economy, eco-efficiency and recognition of biogas as an economic asset, the law is clear about characterising all the economic and social aspects involved in biogas production. It is these principles that underpin and justify the very existence of the Law and it is through them that the public administration and those involved in the biogas production chain should be guided in the development of their activities.
The law's objectives address more specific issues.

> Art. 6 The objectives of this Law are:
>
> I - encourage and expand the participation of renewable energies in the national energy matrix through the generation of combustible gases from biomass;

II - to reduce negative impacts on the environment from agro-industry activities and the disposal of sanitation waste; its use on an industrial and commercial scale, as a way of generating employment and social development;

III - to encourage the utilisation of biomass and biodigestion through its use on an industrial and commercial scale, as a means of generating employment and social development;

IV - stimulate the technological development of biogas, biomethane, biomass and derived products;

V - diversify the Brazilian energy matrix by increasing the share of renewable sources from biogas, biomethane and biomass;

VI - assist in achieving the targets for reducing greenhouse gas emissions;

VII - encourage research and development related to the production and utilisation of biogas, biomethane and associated co-products;

VII - encourage the use of biomethane in public transport;

IX - encourage the use of digestate, after appropriate treatment, in soil fertilisation, including in public areas;

X - encourage the integration of the production and use of biomethane and natural gas through existing and future gas pipelines;

XI - encourage the creation of companies that have appropriate national technologies for developing and producing the equipment needed to produce and utilise biogas, biomethane and associated co-products;

XII - stimulate the production and transformation capacity of biomass into energy, green chemistry and renewable materials; and

XIII - to promote the logistical infrastructure needed to mobilise biomass and promote the internalisation and expansion of the use of biogas and biomethane.

The use of existing gas pipelines is provided for in item X, the intention of which is to enable the production chain to make use of already established infrastructure, a fact that can be decisive for the economy of the process. In section XI, the legislator sought to stimulate the production of equipment needed for biogas production by the domestic industry. In the case of the Mele project, located in Paraná, thought should be given to the network of pipelines available from COMPAGÁS and the licence processes for building new pipelines.

It is also important to highlight the incentive to use pipelines for transporting biogas and not for transporting inputs used in the production process.

1.4. Programme Institution

Article 7 establishes the Incentive Programme for the Production and Use of Biogas and Biomethane and Associated Products - PIBB, which, as the text of the Bill makes clear, has the main objective of articulating the production chain and consolidating biogas and biomethane in the country's energy matrix.

Art. 7 The Incentive Programme for the Production and Use of Biogas and Biomethane and Associated By-Products - PIBB is hereby established with the aim of coordinating energy generation initiatives and consolidating biogas and biomethane in the Brazilian energy matrix.

§ Paragraph 1 The Federal Government shall adopt measures to encourage the production of biogas and biomethane, with the aim of stimulating the internalisation of the supply of biomethane;

§ Paragraph 2 The Federal Government shall adopt measures to map the generation of organic waste that can be converted into renewable energy and the regional potential for producing energy crops.

§ Paragraph 3 The Federal Government must regulate the possible use of biogas as a process gas or raw material for the bioeconomy, which considers the use of renewable raw materials to replace oil derivatives for the production not only of biofuels and bioproducts.

The internalisation of the supply of biomethane referred to in paragraph 1 aims to supply the interior of the country with the use of this energy modality, creating the conditions for the entire national territory to be able to make use of it. Likewise, by stipulating in paragraph 2 that the Federal Government will map the generation of organic waste in Brazil, the legislator understood that in order to stimulate this, it is necessary to know all the points with production potential. Paragraph 3, on the other hand, makes it clear that the Union has the power to regulate the use of biogas at federal level.

1.5. Incentives and resources

Art. 8 PIBB will be implemented through the following mechanisms:

I - tax incentives designed to promote changes in production patterns and the management of natural resources to incorporate environmental sustainability, as well as to encourage the generation of biogas, biomethane and associated co-products;

II - tax incentives for individuals and companies that invest in the generation of biogas, biomethane and associated co-products;

III - credits with differentiated interest rates for the implementation of infrastructure to generate biogas, biomethane and associated co-products.

Sole Paragraph. The incentives provided for in this law do not exclude other benefits, rebates and deductions in force.

As well as providing tax incentives for biogas producers, the law also makes it possible to grant differentiated credits to participants in the production chain.

Art.9 PIBB will be made up of the following resources, without prejudice to others that may be allocated to it:

I - Union budget appropriations;

II - Union-initiated credit operations signed with multilateral credit organisations and aimed at implementing the PIBB;

III - financial, physical or service counterparts of public or private origin; and

IV - other resources earmarked for the implementation of the PIBB.

§ Paragraph 1 - The Federal Government is authorised to grant an economic subsidy to the National Bank for Economic and Social Development (BNDES), in the form of interest rate equalisation, in PIBB financing

> operations.

When it comes to the resources that will finance the PIBB, the bill includes federal budget appropriations and also credit operations agreed between the federal government and credit institutions. It also establishes the possibility of using physical, financial or service counterparts, among other resources.

The National Bank for Economic and Social Development (BNDES) may receive economic subsidies from the Federal Government as equalisation of interest rates, to open specific lines of financing for investments in the biogas production chain.

1.6. Research

The legislator also sought to create mechanisms to incentivize research into biogas. This incentive will be provided by means of open calls for research involving technological development and innovation.

> Art. 10 Research, development and innovation projects that effectively develop viable solutions for increasing the production and utilisation of biogas, biomethane and associated co-products will be financed by the Federal Government, by means of open calls for tender.

1.7. Plumbing

> Art. 11 - The Federal Government, through the Ministry of Mines and Energy and the ANP, shall work with the states and the Federal District to harmonise and improve the rules governing the provision of local piped gas services, especially as regards the possibility of injecting biomethane into the natural gas distribution network and the conditions for opening up the gas market.

The use of existing gas pipeline networks should be articulated between the Union and the states, as determined by the text of article 11. This is an attempt to encourage an integrated, practical and economical approach to establishing the biogas market.

2. DECREE NO. 11.003/2022 - FEDERAL STRATEGY TO ENCOURAGE THE SUSTAINABLE USE OF BIOGAS AND BIOMETHANE

DECREE NO. 11.003/2022 - FEDERAL STRATEGY FOR THE SUSTAINABLE USE OF BIOGAS AND BIOMETHANE
(https://www.planalto.gov.br/ccivil_03/_Ato2019-2022/2022/Decreto/D11003.htm)

This legislation establishes the Federal Strategy to Encourage the Sustainable Use of Biogas and Biomethane. Article 1 sets out the decree's objectives:

> Art. 1 The Federal Strategy to Encourage the Sustainable Use of Biogas and Biomethane is hereby established, with the following objectives:
>
> I - encourage programmes and actions to reduce methane emissions;
>
> II - encourage the use of biogas and biomethane as renewable sources of energy and fuel;
>
> III - to contribute to the fulfilment of the commitments undertaken by the country within the scope of:
>
> > the United Nations Framework Convention on Climate Change, promulgated by Decree No. 2,652 of 1 July 1998;
> > the Glasgow Climate Pact;
> > and Commitment.

The article seeks to align federal policy with the international environmental pacts to which Brazil is a signatory. This initiative reinforces the sustainable nature of introducing biogas and biomethane into the Brazilian energy mix, in line with the main objective of reducing methane emissions into the environment.

In Article 2, the Decree stipulates that public administration bodies will apply the content of this Federal Policy when it is necessary for the fulfilment of local actions and strategies.

Article 3 provides the usual definitions of the terms pertinent to the energy model, adding the expression "methane credit", which refers to the representation of one tonne of methane that has not been dumped into the environment.

> Art. 3 For the purposes of this Decree, the following are considered:
>
> I - Biogas - raw gas whose composition contains methane obtained from renewable raw materials or organic waste;
>
> II - Biomethane - gaseous biofuel consisting essentially of methane derived from the purification of biogas, in compliance with the specifications established by the National Petroleum, Natural Gas and Biofuels Agency (ANP);
>
> III - Methane credit - representing one tonne of methane that is no longer emitted into the atmosphere; and
>
> IV - Vehicular natural gas - denomination of gaseous fuel, typically derived from natural gas, biomethane or a mixture of both, intended for vehicular use, the main component of which is methane, subject to the specifications established by the ANP.

2.1 Guidelines and instruments

> Art. 4. The guidelines of the Federal Strategy to Encourage the Sustainable Use of Biogas and Biomethane are:

I - encourage the carbon market, particularly in terms of methane credit;

II - encourage the drawing up of plans and the signing of sectoral agreements;

III - promote the implementation of biodigesters, biogas purification systems and biomethane production and compression systems;

IV - promote initiatives for fuelling light and heavy vehicles, such as buses, lorries and agricultural tractors, and vessels powered by biomethane or biomethane hybrids, such as green points and corridors;

V - promote the implementation of technologies that enable the use of biogas and biomethane as renewable energy and fuel sources;

VI - promote the development of scientific-technological research and innovation, and the dissemination of technologies, processes and practices aimed at mitigating emissions from methane sources;

VII - promote measures and mechanisms to encourage the reduction of methane emissions;

VIII - promote national and international co-operation for the financing, training, development, transfer and dissemination of technologies and processes for the implementation of actions to reduce methane emissions.

In the article on guidelines, the legislator sought to reinforce all the initiatives that will make it possible to consolidate the biogas production chain in Brazil.

Encouraging research and the implementation of new technologies, trade and sectoral agreements and fostering the industrial development of the sector are among them. It is important to emphasise the definition of methane credits and the carbon market. Reducing methane emissions into the atmosphere is part of the proposed guidelines and is in line with the environmental pacts that Brazil has signed.

Article 5, in turn, establishes the instruments that the Federal Strategy uses to achieve its objectives:

Art. 5. The following are instruments of the Federal Strategy to Encourage the Sustainable Use of Biogas and Biomethane:

I - National Green Growth Programme;

II - National Climate Change Fund;

III - scientific research, especially that carried out through funding agencies; and

IV - National Biofuels Policy - RenovaBio.

The **National Green Growth Programme** is an initiative that aims to offer funding and subsidies to encourage sustainable economic projects and activities, prioritise the granting of environmental permits and generate so-called "green jobs".

The **National Climate Change Fund is** intended to finance projects, studies and undertakings aimed at reducing greenhouse gas emissions and adapting to the effects of climate change.

Renovabio, mentioned in the article, will be explained in detail in the last chapter of this report.

Article 6 deals with the implementation of the Federal Strategy in terms of its governance, integration and coordination:

> Art. 6. The governance, integration and coordination of the actions required to implement the Federal Strategy to Encourage the Sustainable Use of Biogas and Biomethane will be carried out within the scope of the Interministerial Committee on Climate Change and Green Growth, referred to in Decree No. 10.845, of 25 October 2021.

The attributions and scope of the Interministerial Committee on Climate Change and Green Growth (CIMV) are set out in Decree 10.845/2021. Article 1 states that the Committee is permanent and has the purpose of establishing guidelines, articulating and coordinating the implementation of the country's public actions and policies relating to climate change.

The executive branch's public policies, development plans and government programmes will be made compatible with the guidelines and recommendations established in the CIMV resolutions.

Among its duties, the CIMV is responsible for Brazil's strategy towards the United Nations Framework Convention on Climate Change (UNFCCC) and the definition of Brazil's Nationally Determined Contributions (NDCs) under the Paris Agreement. In this context, it is the Committee responsible for establishing the specific guidelines and standards of the National Green Growth Programme.

Representatives of federal public bodies and entities; representatives of the states, the Federal District and municipalities; and personalities with notable knowledge of the subject may be invited to take part in CIMV meetings, without the right to vote.

In Article 7, the Strategy lists the sources of biogas and biomethane:

> Art. 7. The main sources of biogas and biomethane considered within the scope of the Federal Strategy to Encourage the Sustainable Use of Biogas and Biomethane are urban and rural waste, including, among others:
>
> I - waste disposed of in landfill sites;
>
> II - waste generated in sewage treatment plants;
>
> III - waste from the sugar-energy chain; and
>
> IV - waste from pig farming, poultry farming and others.
>
> Sole Paragraph. Other sources of biogas and biomethane are permitted, provided they fulfil the criteria and procedures established by the competent bodies.

Subsection IV clearly lists pig, poultry and other waste as sources of biogas and biomethane, which puts the state of Paraná at an advantage, considering that it has one of the largest reserves of such waste in the world.

3. NORMATIVE ORDINANCE NO. 19/GM/MME - PROCEDURES FOR APPROVING PIPELINE PROJECTS IN THE OIL, NATURAL GAS AND BIOFUELS SECTOR AND NATURAL GAS PRODUCTION AND PROCESSING INFRASTRUCTURE TO THE SPECIAL INCENTIVE SCHEME FOR INFRASTRUCTURE DEVELOPMENT (REIDI)

NORMATIVE DECREE NO. 19/GM/MME

(https://antigo.mme.gov.br/web/guest/acesso-a-informacao/legislacao/portarias/-/document_library_display/mhGvQg5HAvT2/view/1392006?_110_INSTANCE_mhGvQg5HAvT2_topLink=home&_110_INSTANCE_mhGvQg5HAvT2_delta2=20&_110_INSTANCE_mhGvQg5HAvT2_keywords=&_110_INSTANCE_mhGvQg5HAvT2_advancedSearch=false&_110_INSTANCE_mhGvQg5HAvT2_andOperator=true&p_r_p_564233524_resetCur=false&_110_INSTANCE_mhGvQg5HAvT2_cur2=15)

This decree establishes the procedures for approving pipeline projects in the oil, natural gas and biofuels sector and natural gas production and processing infrastructure for the Special Incentive Regime for Infrastructure Development - REIDI.

We bring up this piece of legislation for information purposes, as the New Gas Law (Law No. 14,134/2021 and Decree No. 10,712/2021) establishes that any gas that does not fall within the definition of natural gas defined in the Law will be given equivalent treatment, as long as it can meet the specifications established by the ANP, such as biomethane.

There is no ANP Resolution dealing with biogas, only biomethane. However, we believe that some tax incentives for biomethane and fuel transport can be claimed for biogas, if the project includes pipelines for its transport.

The fact that biogas can be used as a fuel and as a source of hydrogen for the production of e-fuels may allow it to be specially categorised so that it can also receive the incentive of REIDI - the Special Incentive Regime for the Development of Infrastructure, provided for in the MME Ordinance.

> Art. 1. A private legal entity that owns an infrastructure project in the oil, natural gas, derivatives and biofuels sector may apply to have its project included in the Special Incentive Regime for Infrastructure Development - REIDI.
>
> § The infrastructure projects referred to in the heading must be the subject of a permit, authorisation or concession, under the terms of the legislation and regulations in force, and fall into one of the following categories:
>
> I - **fuel transport pipelines**;
>
> II - **fuel transfer pipelines**;
>
> III - **gas pipelines regulated by the National Petroleum, Natural Gas and Biofuels Agency (ANP)**;
>
> IV - pipelines for the provision of local piped gas services;
>
> V - production of non-associated natural gas and **biomethane production**; and
>
> VI - natural gas processing.
>
> 2º. For the purposes of this Ordinance, a project is defined as a work or group of works related to the same undertaking, with a defined deadline and scope.

§ 3º. The owner of an infrastructure project is considered to be the legal entity that carries out the project, incorporating the infrastructure work into its fixed assets.

Normative Ordinance 19/GM/MME, although it does not specifically mention biogas, provides for tax exemption for pipelines that can be classified for the transport and transfer of fuels, as well as for gas pipelines under ANP regulation, and for the production of non-associated natural gas and biomethane production.

The inclusion of non-associated gas and biomethane in the Ordinance is part of the National Programme for Measures to Promote the Production and Sustainable Use of Biomethane.

As there is a whole national public policy to encourage biogas, it is very likely that there will be a change in the Ordinance to include biogas explicitly.

For this reason, at the present time, we believe that the granting of the REIDI benefit for biogas pipelines will be favourable within the possibilities currently provided for in the Ordinance.

It is important to emphasise that the ANP currently only has resolutions relating to biomethane and not biogas specifically. Studies on biogas, such as Embrapa's[24] , comply by analogy with ANP Resolution 16/2008.

By way of background, the ANP resolutions on biomethane are as follows:

Biomethane specifications in Brazil are regulated by the following resolutions:
ANP Resolution No. 906/2022 - Provides for the specifications of biomethane from organic agroforestry and commercial products and waste intended for vehicular use and for residential and commercial installations to be marketed throughout the national territory.

ANP Resolution No. 886/2022 - Establishes the specification and rules for approving the quality control of biomethane from landfills and sewage treatment plants for use in vehicles and residential, industrial and commercial installations, to be marketed in Brazil.

The Special Incentive Scheme for Infrastructure Development (REIDI) aims to provide tax relief for the implementation of infrastructure projects. A legal entity that has an approved project to implement works in various areas, including energy production and distribution, becomes a beneficiary of REIDI.

REIDI, established by Law No. 11.488/2007 and regulated by Decree No. 6.144/2007, suspends the requirement to pay the PIS/PASEP and COFINS contributions on purchases and imports of goods and services linked to the approved infrastructure project, carried out within a period of five years from the date of qualification of the legal entity that owns the infrastructure project.

Adherence to the regime depends on the legal entity's fiscal regularity in relation to the taxes and contributions administered by the Federal Revenue Service, in order to have the PIS (1.65%) and COFINS (7.6%) contributions suspended on revenues from acquisitions intended for use or incorporation in infrastructure works.

[24] https://www.embrapa.br/suinos-e-aves/biogasfert/biogas/padronizacao-e-qualidade/qualidade-e-normatizacao

Within the scope of the electricity sector, REIDI beneficiaries can apply for qualification and co-qualification by a private legal entity that has a project to implement infrastructure works in the energy sectors, including the generation, co-generation, transmission and distribution of electricity.

In this sense, Ordinance 19 equated pipelines with the concept of infrastructure projects, extending the benefits of REIDI to projects that expand the use of pipelines in Brazil.

Ordinance 19 establishes the procedures for obtaining the benefit, with the ANP being the regulatory agency authorising the benefit.

Art. 2. The application for the project's classification must be made:

I - to the ANP, in the case of projects in the categories of Article 1, paragraph 1, items I to III, V and VI; and

...

§ 1º. The application referred to in the heading must be made using the form in Annex I, completed and signed by the legal representatives with management powers, in accordance with the articles of association of the legal entity that is the project's owner, by the technical manager and the accountant of the legal entity that is the project's owner, accompanied by the following information and documents:

I - the legal entity that owns the project:
a) corporate name;
b) registration number with the National Registry of Legal Entities (CNPJ); and
c) name and Individual Taxpayer Registration Number (CPF) of the legal representatives representatives, the technical manager and the accountant;
II - the infrastructure project:
a) name of the enterprise;
b) the category it falls into, among those indicated in art. 1, § 1;
c) an act granting permission, authorisation, concession or equivalent administrative act issued by the competent body;
d) location of the enterprise: municipalities and states;
e) description of the project, with dimensions, general characteristics and main elements of the project;
f) physical and financial timetable for implementing the project;
g) Indication of the start and end date of the project;
h) the form in Annex I to this Ordinance, signed by the legal representatives, technical manager and accountant of the legal entity holding the project; and
i) in the case of gas pipelines to be included in art. 1, § 1, item IV, as they are gas pipelines with contracts regulated by the State Public Authority, a statement from the competent body, representing the state granting authority, confirming that the positive impact of the REIDI benefit will be taken into account in the definition of piped gas distribution tariffs, in the form of Annex II to this Ordinance, for the purposes of the provisions of art. 6, § 1, item I, of Decree no. 6.144, of 3 July 2007;
III - estimates of the project's investment and the amount of tax suspension resulting from REIDI, under the terms of arts. 2 and 3 of Decree No. 6.144, of 2007, based on the month prior to the date of submission of the application referred to in art. 2, in the form of Annex I to this Ordinance, containing the following information:
a) investments in goods (machinery, equipment and building materials), utilities, etc.
third parties and others to be acquired subject to the Contribution for the Social Integration Programme and the Public Servant's Equity Formation Programme - PIS/Pasep, the Contribution for the PIS/Pasep-Import, the Contribution for the Financing of Social Security - Cofins and Cofins - Import during the period of the Special Regime; and
b) investments in goods (machinery, equipment and construction materials), third-party services and others to be acquired free of PIS/Pasep, PIS/Pasep-Import, Cofins and Cofins-Import during the Special Regime period.
...

Art. 4 The project will be considered to be included in REIDI upon publication of a Ministerial Order from the Ministry of Mines and Energy, which must include:
I - the business name and CNPJ registration number of the legal entity that owns the approved project;
II - a description of the project, specifying the category in which it falls under the terms of art. 1, § 1;
III - estimates of investments and the suspension of taxes resulting from REIDI, which are the sole responsibility of the legal entity that owns the project; and
IV - the estimated start and end date of the project.
...
Art. 10 - The ANP will inform the Ministry of Mines and Energy and the Brazilian Federal Revenue Office of any situations that show that the project has not been implemented in the manner approved by Ordinance.

4. FEDERAL LAW NO. 12.305/2010 - NATIONAL SOLID WASTE POLICY

FEDERAL LAW NO. 12.305/2010 - ESTABLISHES THE NATIONAL SOLID WASTE POLICY

(https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm)

Law 12.305/2010 establishes the National Solid Waste Policy, setting out its principles, objectives and instruments, as well as guidelines for the integrated management and management of solid waste, including hazardous waste, the responsibilities of generators and public authorities and the applicable economic instruments. Individuals or legal entities, whether public or private, who are directly or indirectly responsible for generating solid waste and those who carry out actions related to the integrated management or management of solid waste are subject to compliance with this Law. (art. 1)

This law sets out the content of the National Solid Waste Policy, which is applicable to all natural and legal persons who are directly or indirectly linked to activities involving solid waste.

Article 13 of the Law classifies solid waste for the purposes of the Law, with some classifications that apply to the Mele project.

I - as to origin:

f) industrial waste: waste generated in production processes and industrial facilities;

i) agroforestry waste: waste generated in agricultural and forestry activities, including waste related to inputs used in these activities;

The law lays down general obligations for those in production chains that generate or use solid waste, such as the Federal Technical Register of Potentially Polluting Activities or Activities that Use Environmental Resources; compliance with stipulated environmental standards; carrying out environmental inventories; obtaining environmental licences; and others.

Various legal concepts were also introduced by the law, such as the concepts of contaminated area, life cycle, environmentally appropriate final destination, solid waste generators, integrated solid waste management, reverse logistics, sustainable production and consumption patterns, waste, solid waste, shared responsibility for the life cycle of products, and others.

Article 9 provides for the use of technologies for the energy recovery of solid waste.

Art. 9o In the management of solid waste, the following order of priority must be observed: non-generation, reduction, reuse, recycling, treatment of solid waste and environmentally appropriate final disposal of waste.

§ 1o Technologies for the energy recovery of solid urban waste may be used, provided their technical and environmental viability has been proven and a toxic gas emission monitoring programme approved by the environmental agency has been implemented.

The National Solid Waste Policy stipulates that municipalities must create Municipal Integrated Solid Waste Management Plans (art. 18).

It is therefore important to be aware of whether there is a Municipal Solid Waste Plan in the Municipality of Toledo and Region, and how this Plan deals with pig farming waste in the region.

Article 20 states which activities are subject to the preparation of a **Solid Waste Management Plan**, with **industrial activities falling under this obligation**. **Agricultural and forestry activities, on** the other hand, **are subject to this obligation** if required by the competent body of Sisnama, SNVS or Suasa.

From articles 21 to 23, the law determines the minimum content of a **Solid Waste Management Plan:**

Art. 21 The **solid waste management plan** has the following **minimum content**:

I - description of the enterprise or activity;

II - a diagnosis of the solid waste generated or managed, containing the origin, volume and characterisation of the waste, including the environmental liabilities related to them;

III - in compliance with the rules established by the Sisnama, SNVS and Suasa bodies and, if applicable, the municipal integrated solid waste management plan:

a) explaining who is responsible for each stage of solid waste management;

b) definition of the operational procedures relating to the stages of solid waste management for which the generator is responsible;

IV - identification of consortium solutions or solutions shared with other generators;

V - preventive and corrective actions to be taken in the event of incorrect management or accidents;

VI - targets and procedures related to minimising the generation of solid waste and, subject to the rules established by the Sisnama, SNVS and Suasa bodies, reuse and recycling;

VII - if applicable, actions relating to shared responsibility for the life cycle of products, in accordance with art. 31;

VIII - measures to remedy environmental liabilities related to solid waste;

IX - the frequency of its review, observing, if applicable, the term of the respective operating licence held by the Sisnama bodies.

§ 1o The solid waste management plan will comply with the provisions of the municipality's integrated solid waste management plan, without prejudice to the rules established by the Sisnama, SNVS and Suasa bodies.

§ 2o The absence of a municipal integrated solid waste management plan does not prevent the preparation, implementation or operationalisation of the solid waste management plan.

§ 3o These will be established by regulation:

I - rules on the enforceability and content of the solid waste management plan relating to the work of cooperatives or other forms of association of collectors of reusable and recyclable materials;

II - simplified criteria and procedures for submitting solid waste management plans for micro and small companies, as defined in items I and II of art. 3º of Complementary Lawº 123, of 14 December 2006, provided that the activities they carry out do not generate hazardous waste.

Art. 22 A duly qualified technical manager will be appointed to draw up, implement, operate and monitor all the stages of the solid waste management plan, including the control of the environmentally appropriate final disposal of waste.

Art. 23 Those responsible for a solid waste management plan shall keep complete information on the implementation and operation of the plan under their responsibility up to date and available to the competent municipal body, the licensing body of Sisnama and other authorities.

Law No. 12.305/2010 is regulated by Decree No. 10.936/2022, which provides a series of details about the Solid Waste Management Plan for companies and municipalities.

5. FEDERAL LAW NO. 13.576/2017 - FEDERAL BIOFUELS POLICY RENOVABIO

FEDERAL LAW NO. 13.576/2017 - FEDERAL BIOFUELS POLICY - RENOVABIO)
(https://www.planalto.gov.br/ccivil_03/_Ato2015-2018/2017/Lei/L13576.htm)

5.1 Objectives

Article 1 of the **National Biofuels Policy** lists its main objectives:

> **Art. 1** The National Biofuels Policy (RenovaBio) is hereby established as an integral part of the national energy policy referred to in art. 1 of Law no. 9478 of 6 August 1997, with the following objectives:
>
> I - contribute to meeting the country's commitments under the Paris Agreement under the United Nations Framework Convention on Climate Change;
>
> II - to contribute to the appropriate ratio of energy efficiency and reduction of greenhouse gas emissions in the production, commercialisation and use of biofuels, including through life cycle assessment mechanisms;
>
> III - to promote the adequate expansion of the production and use of biofuels in the national energy matrix, with an emphasis on the regularity of fuel supply; and
>
> IV - to contribute with predictability to the competitive participation of the various biofuels in the national fuel market.

It should be noted that concern about climate change and GHG emissions is one of the main objectives of the legislation. In Subsections I and II, the law mentions the commitments of the Paris Agreement, to which Brazil is a signatory, with the aim of increasing biofuels in the energy matrix.

With a view to the energy transition, the Law decided to promote the expansion of biofuel production and use with regularity and predictability, in order to insert the new model into the national supply system, so as to gradually replace fossil fuels, with an emphasis on the regularity of fuel supply.

5.2 How Renovabio works

The **National Biofuel Policy (RenovaBio)** instituted by Law 13.576/2017 has the main objective of boosting **biofuel** production in the Brazilian energy matrix, based on predictability and environmental, economic and social sustainability.

Among its targets is to reduce GHG emissions by 37 per cent below 2005 levels by 2025, and a consequent 43 per cent reduction below 2005 emission levels by 2030.

The programme has other objectives, such as:

Contribute to the fulfilment of Brazil's commitments under the Paris Agreement;

Promote increased production and consumption of renewable fuels in the energy mix and regularisation of fuel supplies;

Ensuring predictability for the fuel market, generating energy efficiency gains and mitigating emissions of pollutants and greenhouse gases in the production, commercialisation and use of biofuels.

In practice, the programme establishes annual national decarbonisation targets for the fuel sector, authorising the purchase of Decarbonisation Credits (CBIO) according to the volume of biofuel production.

> The biofuels that currently benefit from the incentive are ethanol and biomethane, but energy policy will certainly move towards encouraging new sources, such as *green fuels* and hydrogen generated using biomass, which has the same production principle as biomethane.

The reduction of GHG emissions can be achieved through the generation of electricity from biomass and the production of biomethane. RenovaBio provides market conditions that favour the sector, with the inclusion of biomethane as an alternative for supplying decarbonisation credits (CBIOs), which are securities traded on the securities market.

Decarbonisation credits (CBIOs) are a pricing model that result in a reduction in carbon emissions and must be purchased annually by fuel distributors. CBIOs are issued by duly certified biofuel producers/importers in proportion to the volumes sold of these products and the Environmental Energy Efficiency Index. These decarbonisation credits are used to mitigate part of Brazil's greenhouse gas (GHG) emission reduction targets under the Paris Agreement.

The programme stipulates that biofuel producers/importers will have up to 60 days to issue the CBIO after its sale, and the primary issue of the CBIO will be formulated by means of a deed. The bookkeeper must keep records of the trades carried out during the period in which the credits are registered, so that the CBIOs can be traded on exchanges, either by the bookkeeper itself or by a broker. These credits can be acquired by distributors, investors, hedge funds and other market agents, and the exchange must publicise the trades at the end of each day.

5.3 Renovabio's Strategic Axes

Three strategic axes guide Renovabio:

1. GHG emission reduction targets;
2. Certification of biofuel production;
3. Decarbonisation Credit (CBio).

The first strategic axis takes place when the government, through the **National Energy Policy Council (CNPE), establishes annual national decarbonisation targets for** a 10-year period, in accordance with the targets of **Decree No. 9,888 of 27 June 2019**.

These targets are extended by the National Petroleum, Natural Gas and Biofuels Agency (ANP) to fuel distributors. At this stage, the plants are audited with regard to GHG emissions in their production stages. Through this survey, a carbon intensity index (CI) is generated. A low index means fewer greenhouse gas emissions.

The second axis depends on **voluntary action by biofuel producers, who are the primary emitters in RenovaBio**. Production certification is based on Life Cycle Analysis (LCA), in accordance with **ANP Resolution 758 of 23**

November 2018.

In this way, certified producers receive energy and environmental efficiency scores, which are multiplied by the volume of biofuel that will be marketed, in compliance with RenovaBio's eligibility criteria, and which will result in the quantity of decabornisation credits (CBIOs) that each producer will be authorised to issue and trade on the market.

The Environmental Energy Efficiency score is the difference between the carbon intensity index of the biofuel and the carbon intensity index of the fossil fuel.

Finally, in the third strategic axis, national and individual metals are now defined in units of decarbonisation credits (CBIOS), an environmental asset equivalent to one tonne of carbon dioxide not emitted. A

The environmental energy efficiency score is multiplied by the amount of biofuel commercialised, determining how many CBIOs the company can sell. CBIOs are then made available for trading on the stock exchange. They must be purchased by distributors until they are withdrawn from the market by 31 March of the following year, in order to prove compliance with the targets set by the ANP. According to a report released by the National Petroleum, Natural Gas and Biofuels Agency (ANP), by November 2021 there were 300 biofuel producers with approved and active certification.

Decree No. 9.888/2019 provides for the definition of compulsory annual greenhouse gas emission reduction targets for the commercialisation of fuels under Law No. 13.576/2017, and establishes the National Biofuels Policy Committee - RenovaBio Committee.

6. MMA DECREE NO. 71/2022 - NATIONAL METHANE EMISSIONS REDUCTION PROGRAMME - ZERO METHANE

MMA ORDINANCE NO. 71/2022 - NATIONAL METHANE EMISSIONS REDUCTION PROGRAMME - ZERO METHANE

(https://in.gov.br/en/web/dou/-/portaria-mma-n-71-de-21-de-marco-de-2022-387378473)

As part of the Federal Strategy to Encourage the Sustainable Use of Biogas and Biomethane. established by Decree No. 11.003/2022, MMA Ordinance No. 71/2022 instituted the National Methane Emissions Reduction Programme - Methane Zero, the main objective of which is to contribute to the country's commitments under the United Nations Framework Convention on Climate Change, the Glasgow Pact and the Global Methane Agreement.
Article 3 sets out the programme's objectives:

> Art. 3 The strategic objectives of the Zero Methane Programme are:
>
> I - the reduction of methane emissions;
>
> II - the sustainable use of biogas and biomethane as renewable sources of energy and fuel;
>
> III - promote sectoral agreements aimed at the sustainable use of biogas and biomethane and the reduction of methane emissions.

The Programme's guidelines, outlined in Article 4, set out the axes that the federal government intends to encourage for the expansion of biogas and biomethane in the Brazilian energy matrix.

> Art. 4 The guidelines of the Zero Methane Programme are:
>
> I - encourage the carbon market, especially methane credit;
>
> II - promote sectoral plans and agreements;
>
> III - promote the implementation of biodigesters and systems for purifying biogas and producing and compressing biomethane;
>
> IV - encourage the creation of green points and corridors for fuelling light and heavy vehicles, such as buses, lorries and agricultural tractors, and boats powered by biomethane or biomethane hybrids;
>
> V - encourage the implementation of technologies that enable the use of biogas and biomethane as renewable energy and fuel sources;
>
> VI - promote and develop scientific-technological research and innovation, and the dissemination of technologies, processes and practices aimed at mitigating emissions from methane sources;
>
> VII - encourage measures and mechanisms to stimulate the reduction of methane emissions; and
>
> VIII - promote national and international co-operation for the financing, training, development, transfer and dissemination of technologies and processes for the implementation of actions to reduce methane emissions.

The instruments of the Zero Methane Programme, listed in Article 5, have already been mentioned in Decree No. 11.003/2022, which are:

- National Green Growth Programme
- National Climate Change Fund
- The research lines of funding agencies

The Zero Methane Programme will be coordinated by the Secretariat for Environmental Quality, in conjunction with the Secretariat for Climate and International Relations of the Ministry of the Environment (Art. 6).

LEGAL REGULATORY REPORT ON BIOGAS IN THE STATE OF PARANÁ

H2UPPP PROJECT - MELE BIOGAS GmbH

SIGLAS

AAA Environmental Authorisation
ABIOGAS Brazilian Biogas Association
AF Forestry Authorisation
AGEPARA Regulatory Agency for Delegated Public Services in the State of Paraná
ANEEL Agência Nacional de Energia Elétrica
National Petroleum and Biofuels Agency
BNDES National Bank for Economic and Social Development
BRDE Banco Regional de Desenvolvimento Econômico e Social do Extremo SUl
CBIO Decarbonisation Credit of the National Biofuel Policy - RenovaBio
Hydroelectric Generating Centre
CIBIOGAS International Renewable Energy Centre
COMPAGÁS Companhia Paranaense de Gás
CONFAZ National Finance Policy Council
COPEL Companhia Paranaense de Energia Elétrica
DLAE Declaration of Exemption from Environmental Licensing
EIA/RIMA Environmental Impact Assessment/Environmental Impact Report
FINEP Financier of Federal Government Projects
Greenhouse Gases
GEFF Global Environment Facility
GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit
IBAMA Brazilian Institute for the Environment and Renewable Natural Resources
ICMS Tax on the Circulation of Goods and Services
IAT Water and Land Institute
LAC Environmental Licence for Adherence and Commitment
LAS Simplified Environmental Licensing
Installation Licence
LOL Operating Licence
Prior Licence
MCTI Ministry of Science, Technology and Innovation
Sustainable Development Goals
Small Hydroelectric Power Plant
PERSP State Solid Waste Plan for the State of Paraná
Reverse Logistics Plan
PNRSP National Solid Waste Plan
PPP Public-Private Partnership
RENOVABI National Biofuels Policy
RICMS/PR Regulation of the Tax on Operations Relating to the Circulation of Goods and on the Provision of Interstate and Intermunicipal Transport and Communication Services in the State of Paraná
SEAB Secretariat of Agriculture and Supply of the State of Paraná
SEDEST Secretariat for Sustainable Development of the State of Paraná
SEFA Secretariat of Finance of the State of Paraná
SEMASecretariat of the Environment of the State of Paraná
SETI Secretariat of Science, Technology and Higher Education of the State of Paraná

Environmental Management System
TECPAR Paraná Institute of Technology
UNIDOO United Nations Industrial Development Organisation

1 STATE LAW NO. 19.500/2018 STATE POLICY ON BIOGAS AND BIOMETHANE IN PARANÁ

STATE LAW NO. 19.500/2018 (STATE BIOGAS AND BIOMETHANE POLICY IN PARANÁ)
(https://leisestaduais.com.br/pr/lei-ordinaria-n-19500-2018-parana-dispoe-sobre-a-politica-estadual-do-biogas-e-biometano-e-adota-outras-providencias)

1.1 General aspects of the law

Biogas is a renewable energy source and comes from the mixture of gases resulting from the anaerobic biodigestion of organic waste, such as food waste, agro-industrial effluents and sewage. Paraná established the legal framework for biogas through State Law 19,500/2018.

Biogas can be used as a fuel gas to generate electricity through generators and also to produce thermal energy that can be used in boilers in industries.

In the form of biomethane, biogas can be used as a substitute fuel for vehicular natural gas, in accordance with a specific ANP Resolution.

Biogas is one of the renewable sources available in nature and can generate electricity, thermal energy and fuel. Another product that can be extracted from biogas processing is biofertilisers for agricultural use, a process that involves the sustainable management of organic waste by the agro-industry and in urban spaces through the production of biogas.

Paraná was a pioneer in encouraging the use of biogas in Distributed Generation when it instituted the State Policy for Distributed Generation with Renewable Energies (Law 17.188/2012).

It is expected that by 2030 Paraná will have 10,000 biogas-generating properties in the state25 .

Investing in biogas brings economic, social and environmental sustainability, promoting the sustainable disposal of waste from the production chain and reducing business costs by generating its own energy and fuel.

Aware of the energy potential of its agro-industrial vocation, in May 2018 Paraná's Legislative Assembly passed Law No. 19,500/2018, which defined the State Policy for the Use of Biogas and Biomethane, stipulating rules, obligations and instruments for organising, encouraging, supervising and supporting the production chains of materials derived from the decomposition of organic matter.

The law also places an obligation on the government to encourage the production and consumption of biogas and biomethane generated in Paraná, by developing specific programmes that promote, among other things, the establishment of tariffs and minimum prices.

The creation of the Regulatory Framework for Biogas and Biomethane in Paraná arose as an economic demand for the state of Paraná, due to the representativeness of agribusiness in the state's GDP and the preservation of the environment.

The creation of State Law No. 19,500/2018 aimed to develop a circular economy to make the state more competitive, based on sustainable guidelines, given that the environmental liabilities of farming and cities are converted into energy assets, thus also solving an environmental problem through the energy utilisation of waste.

[25] https://www.idrparana.pr.gov.br/Noticia/IDR-Parana-incentiva-uso-de-energias-renovaveis

The law is in line with the Paraná Renewable Energy Programme (Decree 11.671/2014), which proposes differentiated incentives and investments in environmental sustainability through the application of a low-carbon economy.

The text of Law No. 19,500/2018 sought to be in line with the main initiatives to promote biogas in Brazil, in particular the "Biogas Applications in Brazilian Agroindustry" Project (GEF Biogás Brasil)26 , an initiative led by the Ministry of Science, Technology and Innovation (MCTI), which brings together international organisations, the private sector, sectoral entities and the Federal Government, with the aim of diversifying the country's energy matrix by enabling the use of biogas.
The project is implemented by the United Nations Industrial Development Organisation (UNIDO)27 and is funded by the Global Environment Facility (GEF)28 and its main executing entity is the International Renewable Energy Centre (CIBiogás)29.

1.2 General Provisions

> Art. 1. Establishes the State Policy for Biogas, Biomethane and other products and rights derived from the decomposition of organic matter (biodigestion), which establishes principles, rules, obligations and instruments for organising, encouraging, supervising and supporting production chains, whether integrated or not, with a view to tackling climate change and promoting regional development with environmental, economic and social sustainability.

Article 1 of Law No. 19,500/2018 establishes the general guidelines and topics that will be addressed by the law. The creation of the Law marks a pioneering move on the part of Paraná, as it was the first state in the Union to pass specific legislation on the subject. It lays down the rights and obligations of producers of this type of energy, as well as the supervision and financial incentives that can be claimed by producers.

Article 2 establishes the specific concepts and terminology contained in the text of the Law, which conceptualise the main elements of the biogas production chain. This clear provision of concepts in the Law is very important, since its understanding and interpretation must be unique among producers, the government, investors and others involved in the production chain.

Any doubt about the exact scope of any of these terms could lead to contractual and regulatory problems in the future, and therefore their meaning must be strictly delimited by legislation.

The production chain for biogas (item I), biomethane and other products and rights derived from the decomposition of organic matter (biodigestion) is defined, for example, as "the set of activities and undertakings linked to each other by contractual relationships and forming part of sectors of the economy that use, produce, generate, industrialise, distribute, provide services, transport or commercialise products and rights derived from biodigestion, including solid waste and effluents".

Solid waste (item II), in turn, is defined as "the discarded material, substance, object or good resulting from human, agricultural, livestock, industrial, commercial, housing, urban, transport, composting and service provision activities, among others, in solid or semi-solid states". Other materials that do not meet these specifications are not included in the Biogas Policy.

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[26] https://www.gefbiogas.org.br/sobreoprojeto.html
[27] https://www.unido.org/
[28] https://www.funbio.org.br/agencias/agencia-gef/
[29] https://cibiogas.org/

Similarly, the law defines effluents (section III) as "liquid waste from industrial establishments (industrial effluent), from human activities (domestic effluent or sewage) and from rainwater networks, which is discharged into the environment in the form of liquids or gases".

The Law also establishes specific concepts such as:

> IV - biodigestion: the process of decomposing organic matter in the absence of oxygen, transforming it into new products by altering its physical, chemical and biological properties;
> V - biogas: raw gas obtained from the biological decomposition of organic products or waste;
> VI - biomethane: gaseous biofuel consisting essentially of methane, derived from the purification of biogas, in the specifications defined by the competent authorities in a regulatory act;
> VII - organic fertiliser: a product of a fundamentally organic nature, obtained by a physical, chemical, physicochemical or biochemical process, natural or controlled, from raw materials of industrial, urban or rural, vegetable or animal origin, whether or not enriched with mineral nutrients;
> VIII - biofertiliser: a product containing an active ingredient or organic agent free of agrotoxic substances, capable of acting directly or indirectly on all or part of cultivated plants, increasing their productivity, without taking into account its hormonal or stimulant value;

These definitions are essential, for example, for the regulation of concessions for the construction and operation of biogas pipelines and biomethane plants.

When it comes to operators in the biogas and biomethane chain, the law provides the following definitions:

> IX - waste and effluent generator: natural or legal persons who generate waste and effluents in their activities;
> X - biogas producer: an individual or legal entity that produces biogas from the decomposition of organic matter and uses it directly or sells it;
> XI - biomethane producer: a natural or legal person, duly authorised by the competent authority, who purifies biogas in order to obtain biomethane;

Let's see that according to the law's definition, pig producers, who supply the raw material for biogas, fall within the biogas production chain as "generators of waste and effluents", since they are the individuals or legal entities that generate waste and effluents in their activities.

The "biogas producer", on the other hand, is the natural or legal person who produces biogas from the decomposition of organic matter and uses it directly or sells it.

Here it will depend on the configuration of the project to determine who will be the biogas producer, since the waste generators (rural pig producers) can supply the waste for biogas production at the plant (which would then be the biogas producer) or they can generate biogas on their properties and sell the biogas to the plant, thus also being biogas producers.

The "biomethane producer" is the natural or legal person, duly authorised by the competent authority, who purifies the biogas in order to obtain biomethane.

It should be noted that the law stipulates a specific authorisation for biomethane producers, which is not required for biogas producers. Biomethane production must follow the specific resolutions of the ANP - National Agency for Petroleum, Natural Gas and Biofuels.

The Law also established the definitions of "**shared and joint responsibility**", which we will discuss in more detail later in this Report, and mentions "**decarbonisation certificates (CBIOS)", an** instrument registered in book-entry form for the purpose of proving the individual target of the fuel distributor, in accordance with Federal Law No. 13.576/2017, which stipulates **RENOVABIO**, a specific incentive programme for the production of biofuels in Brazil;

It is important to mention the last legal concept brought in by the Law, which is the "integrated production chain", conceptualised as the "integration relationship between the integrated rural producer and the integrating agro-industry, under the terms of Federal Law No. 13,288, of 16 May 2016".

Federal Law No. 13,288/2016 provides for vertical integration contracts in agroforestry activities and establishes general obligations and responsibilities for integrated producers and integrators. This law defines vertical integration or integration as "*the contractual relationship between integrated producers and integrators that aims to plan and carry out the production and industrialisation or commercialisation of raw materials, intermediate goods or final consumer goods, with reciprocal responsibilities and obligations established in integration contracts*".

It is an associative and cooperative form (and is considered a cooperative act for legal purposes), where an integrator supports the rural producer with goods, machinery and investments, in order to receive the raw material, input or industrialised good as payment. It's a form brought in by the Law to encourage the creation of a chain between producers and marketers/exporters of agro-industrial goods, in order to facilitate integration and synergy between the activities of rural producers and larger companies called integrators.

It could be a good format to structure between rural producers and the plant (and its investors), who need to receive the biogas for energy use in the production process.

1.3 Civil and Criminal Environmental Liability

CHAPTER II
ENVIRONMENTAL AND HEALTH ASPECTS
Section I

Waste Management
Art. 3 The members of an integrated production chain have shared and joint responsibility for environmental management, which will be organised through Environmental Management Plans, Sectoral Agreements or Terms of Commitment.
Sole Paragraph. The destination or transfer of waste and effluents from one enterprise to another for biodigestion, with the aim of generating biogas or biomethane, is an **appropriate final destination** method, provided that it is licensed and carried out in accordance with the parameters defined in regulations, without prejudice to compliance with the other rules applicable to the activity by the competent environmental bodies.
Section II
Environmental and Health Licensing
Art. 4 Activities involving the **transfer and transport of waste and effluents**, the **production of biogas,** biomethane and the **generation of electricity from biogas** will be licensed by the competent environmental and health authorities, according to their polluting potential and the level of health risk they offer, in accordance with the provisions of the regulations.

1.3.01 Civil Liability

The **National Environmental Policy, instituted by Federal Law No. 6.938/81,** of 31 August 1981, in its article 14, §1º 2, brings the precept of environmental civil liability, and indicates the legal possibilities of objective liability of the polluter, which do not depend on the agent acting with guilt or intent.

The concept of joint and several liability is based on the theory of integral risk, and it is not up to the person responsible for the environmental damage to claim exclusions from civil liability in order to exempt themselves from the obligation and civil responsibility.

In addition, this law establishes the polluter as *"the natural or legal person, under public or private law, responsible, directly or indirectly, for an activity that causes environmental degradation*".

For example, with regard to thermal power plants that use the biogas produced by landfill sites as an input for their final activity (generating electricity), the owners have a direct interest in the landfill sites and benefit economically from them. Consequently, in the event of any environmental damage caused by the poor operation of landfill sites, the owners of the plants will be considered polluters, under the terms of the National Environmental Policy and case law.

When we talk about the risks of setting up and operating thermal power plants fuelled by biogas from landfills, we are also talking about the *propter rem* characteristic linked to environmental obligations.

In accordance with STJ Precedent No. 623, environmental obligations are of a *propter rem* nature and can be collected from the current or previous owner. **The *propter rem* characteristic authorises the owner or possessor of the property, current or previous owners, and other links in the chain, depending on their participation, even if indirect, to demand reparation for environmental degradation.**

From this perspective, contamination of soil and water (groundwater or surface water), even if caused by the carelessness of the owners of rural areas or landfills, can generate obligations for plant operators to recover the environmental quality (remediation of the contamination) of the area, since these operators have partial ownership of the property.

The so-called *propter rem* obligations are linked to the property, i.e. although the owner of the plant may not be the direct cause of environmental degradation (polluter), he assumes environmental conservation obligations due to his ownership of the property or contractual relationship with the producer.

Owners of biogas-fuelled thermal power plants will therefore have to take extra precautions, in that they will have to make sure that not only their plants are environmentally compliant, but also the producers or landfills that supply their inputs.

Ideally, the activities undertaken by the plants and the farmers or landfill owners should be separate and independent. And the contracts for these spaces should clearly stipulate the environmental risks and responsibilities of those involved.

1.3.02 Criminal Liability

With regard to **administrative and criminal environmental liability**, the appropriate punitive measures **can only be applied to those who actually carry out actions typified by environmental law**. This means that in these cases, the so-called Theory of Culpability should be the parameter for imputing penalties, and not a succession of responsibilities. **Any administrative offence and any environmental crimes will be attributed to the perpetrators**.

However, it is worth pointing out that in the case of succession of operators of potentially polluting enterprises, which leads to the continuation of criminal behaviour on the initiative of the new owners and legal guardians of biogas plants, the continuation of the offence may include the new owners in the administrative and criminal penalties provided for by law.

The imputation of these offences applies not only to individuals, but also to legal entities. This is what is prescribed in articles 2 and 3, sole paragraph, of **Federal Law No. 9.605/98 - the Environmental Crimes Law**, which establishes criminal and administrative sanctions that derive from practices harmful to the environment:

> Art. 2 Anyone who, in any way, contributes to the commission of the crimes provided for in this Law shall incur the penalties imposed on them, to the extent of their culpability, as well as the director, administrator, member of the board and technical body, auditor, manager, agent or representative of a legal entity, who, knowing of the criminal conduct of another, fails to prevent its commission, when they could have acted to prevent it.
>
> Art. 3 **Legal entities** shall be held administratively, civilly and criminally liable in accordance with the provisions of this Law, in cases where the offence is committed by decision of their legal or contractual representative, or of their collegiate body, in the interest or benefit of their entity.
>
> Sole Paragraph. The liability of legal entities does not exclude that of natural persons who are authors, co-authors or participants in the same fact.

The **biogas plant's governance rules must provide for the social and environmental risks of its activity**. Through ESG (*Environmental, Social and Governance)* measures, investors and operators can foresee all responsibilities and how they are defined in the company's internal policies and procedures.

1.3.03 Environmental and Health Licensing

The state of Paraná has been issuing regulations on environmental licensing and incentives for the production and use of renewable energy since 2012. State Law 17.188, of 13 June 2012, and Decree 11.671, of 16 July 2014, established the "State Policy for Distributed Generation with Renewable Energy" and its "Paraná Renewable Energy Programme - Illuminating the Future".
The **Analysis of the Legal Framework for Biogas Policy in Paraná, published in August 2022 by the GEF Biogas Brazil project**, recommends that the **Water and Land Institute (IAT)** "regulate the possibility of simplified environmental licensing in the *fast track* modality for such projects, as well as the possibility of including environmental licensing for energy generation, biogas/biomethane and biofertiliser in the same licence the main environmental activity of the producer when that main activity is not the generation of biogas/biomethane or electricity"[30] .
In Paraná there are two types of Authorisation: Environmental (AA) and Forestry (AF):

- **Environmental Authorisation (AA)**: Approves the location and authorises the installation, operation and/or implementation of an activity that may cause alterations to the environment, for a short period, of a temporary nature, or the execution of works that do not characterise permanent installations, in accordance

30 https://datasebrae.com.br/wp-content/uploads/2022/08/IREVIS%C3%83O-OK-112-Avaliacao-do-Marco-Legal-do-Biogas-do-Parana.pdf

with the specifications contained in the approved applications, registrations, plans, programmes and/or projects, including the environmental control measures and other conditions determined by the IAP.

- Forestry Authorisation (AF): Allows the owner of a property to cut down native forest vegetation, isolated trees in a forestry or agricultural environment and use the woody material isolated trees in a forestry or agricultural environment and use the dry woody material. Issued for any procedure involving the removal of material originating from any type of vegetation.

Environmental Licensing, in turn, is divided into three categories:

- Preliminary Licence (LP) - Granted in the preliminary planning phase of the project or activity, approving its location and design, attesting to its environmental viability and establishing the basic requirements and conditions to be met in the next phases of its implementation (PARANÁ, 2008c). Valid for up to 2 years and non-renewable.
- Installation Licence (LI) - Authorises the installation of the undertaking or activity, in accordance with the specifications contained in the approved plans, programmes and projects, including the environmental control measures and other conditions which constitute determining reasons. Valid for up to 2 years with the possibility of renewal.
- Operating Licence (LO) - This authorises the operation of the activity or enterprise, after verification of effective compliance with the provisions of the previous licences, with the environmental control measures and conditions determined for the operation.

Deadlines established according to the typology groups in CEMA Resolution no. 107/2020[31] , and renewable at the IAT's discretion.

1.3.04 Security

As far as safety regulations and inspections by the Fire Brigade are concerned, attention should be paid to the fact that the use of biogas and biomethane in equipment such as boilers and burners has similar characteristics to those used in the use of natural gas, so regulation could be based on similar criteria.

> Art. 5 Biogas and biomethane production and commercialisation operations are subject, if necessary, to inspection by the Paraná State Military Police Fire Department, which may establish fire safety standards in its own regulations, according to the risk potential.

1.3.05 Promotion

Although Article 7 of Law 19.500/2018 contains restrictions on tax policies relating to technological innovation, Article 6 exemplifies programmes to promote the production and consumption of biogas and biomethane generated in Paraná.

> Section II
> Promotion
> Art. 6º . Public authorities are hereby authorised to promote the production and consumption of biogas and biomethane generated in the state of Paraná, by means of specific programmes established by regulation that promote, among other things:
> I - the addition of a minimum percentage of biomethane to the piped gas distributed in the territory of the State of Paraná;
> II - establishing tariffs and minimum prices for biomethane that is added to piped gas distributed in the territory of the State of Paraná;
> III - the purchase of electricity generated from biogas;

[31] https://www.legisweb.com.br/legislacao/?id=401593

IV - the purchase of biomethane to fuel the fleet of official vehicles;
V - the acquisition of decarbonisation certificates (CBIOS);
VI - the creation of a guarantee fund for small-scale biogas or biomethane production projects defined in regulations;
VII - the creation of financing lines at state financial agencies;
VIII - the establishment of public-private partnerships to develop the production chain for biogas, biomethane and other products and rights derived from the decomposition of organic matter (biodigestion).

Law 19,500/2018 established that it is the state government's duty to stimulate the biogas and biomethane chain. To this end, the state is making use of **Fomento Paraná,** a financial institution, company and organization, a mixed-capital company, organised in the form of a privately-held corporation with the majority of its share capital belonging to the State of Paraná.

The institution was created by **State Law 11,741/1997** and authorised to operate by the Central Bank of Brazil on 08/11/1999. Fomento Paraná is a signatory to the Sustainable Development Goals (SDGs), and has been offering credit lines with subsidised interest rates to encourage the installation of equipment capable of generating energy from renewable sources to improve energy efficiency in Paraná companies and institutions.

Among other financing objects, Fomento Paraná's credit lines encourage the acquisition and installation of:

- All the components of micro and mini photovoltaic electricity generation systems, as well as low environmental impact construction projects.
- Solar collectors and heaters, as well as electric, hybrid or biogas-powered motors or equipment with higher energy efficiency ratings or that contribute to reducing greenhouse gas emissions.
- Funding is provided by the BNDES in two lines: one for the purchase of domestic equipment and the other for imported equipment. There is a third possibility via Finep:
    - Acquisition of national equipment - BNDES Climate Fund lines (rates from 4.33% per year) and BNDES Low Carbon (4.48% per year - indexed by Selic)
    - Own resources to finance additional imported components.
    - Finep resources for projects involving elements of innovation.
    - The repayment terms for these loans can be up to 12 years, with a grace period of up to 24 months.

1.3.06 Technological Innovation

Article 7 provides for the possibility of granting tax incentives, financial resources, economic subsidies, among others, to PPP ventures that meet the content of the legislation and are considered technological innovation companies.

CHAPTER IV
TECHNOLOGICAL INNOVATION
Art. 7º . The ventures and productive arrangements that fall under the provisions of this Law, **including in the form of consortiums, condominiums, cooperatives and public-private partnerships, will be considered technological innovation companies, as** referred to in Law no. 17.314, of 24 September 2012, and **may benefit from the** granting of tax incentives, financial resources, economic subsidies, materials or infrastructure, to be adjusted in terms of differentiated tax regimes, special transfer regimes, assignment and use of tax credits, partnerships, agreements or specific contracts, aimed at supporting research and development activities in the territory of Paraná.

Business models for biogas production are local and highly personalised actions and can originate from the initiative of a municipality, an industrial company, a rural producer or any agent with an interest in the energy produced by biogas.

Cosme Polese Borges[32] , who studies the technological innovation system for biogas in Brazil, believes that the solution goes through three planning stages, starting with mapping the potential quantities of biomass, followed by planning the biofuel production process, which is linked to the selection of technology, such as fermentation reactors (biodigesters), landfills (without biodigesters) and effluent treatment plants, each of which will be governed by a specific business model, which will depend on the forecast demand for the fuel.

In this sense, the state legislature understood that such ventures, due to their specificities and strategic value, should be able to access tax incentives, financial resources and economic subsidies, so these benefits were included in Article 7 of Law No. 19,500/2018.

32 https://engemausp.submissao.com.br/21/anais/arquivos/323.pdf

2. SEDEST RESOLUTION NO. 8 OF 23/02/2021 - ENVIRONMENTAL LICENSING OF BIODIGESTERS

SEDEST RESOLUTION NO. 8 OF 23/02/2021 - ENVIRONMENTAL LICENSING OF BIODIGESTERS
(https://www.legislacao.pr.gov.br/legislacao/listarAtosAno.do?action=exibirImpressao&codAto=245464)

2.1 General Aspects of the Resolution

SEDEST Resolution No. 8/2021 deals with Environmental Licensing, definitions, criteria, guidelines and procedures for environmental licensing of **BIODIGESTORS WITH BIOGAS ENERGY USE**.

Environmental Licensing is the administrative procedure carried out by the competent environmental body, which verifies that the legal and technical conditions are met, deciding on general aspects such as the location, installation, expansion, operation and closure of undertakings and activities that use environmental resources that can be classified as effectively or potentially polluting.

Based on these criteria, Article 1 aims to:

> **Art. 1** Establishing definitions, criteria, guidelines and procedures for the environmental licensing of biodigesters, for the purpose of using energy crops, treatment of effluents and organic waste of industrial, urban or rural origin, with energetic use of biogas in the state of Paraná.
> Sole Paragraph. This Resolution also applies to the energetic utilisation of biogas generated in landfills that have already been set up.

The publication of **SEDEST Resolution No. 8 of 23/02/2021,** which deals with the Environmental Licensing of Biodigesters, has brought changes, such as the fact that before the creation of the Paraná Sustainable Energy programme, the average time in the state for an environmental licence to be issued releasing the installation of enterprises that generate energy through biodigesters was 60 days. With the advent of SEDEST Resolution No. 08/2021, the document can be issued even on the same day.

2.2 Definitions

Like other legislation dealing with renewable energies, **SEDEST Resolution 8/2021** provides definitions of key terms. The inclusion of these definitions in the body of the law is necessary to avoid any doubts that could lead to legal issues regarding the implementation of biodigesters.

Chapter I of the Resolution provides a conceptualisation of expressions such as "energy use of biogas", "biogas", "biodigestion or anaerobic digestion", "biodigester", "biomass" and other terms necessary for the proper implementation of such services.

These concepts relate not only to biogas itself, but also to the operators in this process, such as "**biogas producer**", "**biomethane producer"** and "**environmental licence"**. As these are activities that, due to the production process, will necessarily produce waste, it is necessary to understand and legally define each of these terms, precisely to avoid conflicts of interpretation that could lead to doubts and questions about the installation of these devices.

One example is the concept of "**biodigester sludge**", provided for in item XIII of article 2, which is defined as *"solid waste formed by the sedimentation of particles of larger granulometry and low biodegradability that accumulates at the bottom of covered lagoon biodigesters or models without agitation of the biomass and which has considerable nutrient contents that make it possible to use it for soil fertilisation and plant nutrition"*.

Or the concept of a sorting unit, which is *"a place where waste is received and separated according to its material characteristics for subsequent final disposal"*.

In the event of an environmental problem, legal discussions will be guided precisely by the terms set out in the law.

2.3 Environmental Licensing

The Paraná Sustainable Energy programme, launched in March 2022, aims to cut red tape for those seeking environmental licensing for energy production from sustainable sources, with lower greenhouse gas (GHG) emissions. The idea is that producers and entrepreneurs don't need to go through all the environmental licensing stages.

With Sedest Resolution No. 08/2021, the document is now issued more quickly and the request is fully computerised, submitted via the internet to the state's environmental agency, through the Environmental Management System (SGA), developed by the Instituto Água e Terra (IAT).

Environmental licensing is the main content of this law, which in article 3 establishes the relevant administrative acts. The law lists 6 licences that are mandatory for the installation and operation of biodigesters, according to their specifications and polluting potential. These are

> I - Declaration of Waiver of State Environmental Licensing (DLAE): granted to undertakings whose environmental licensing is not the responsibility of the state environmental agency, as established in SEMA Resolution 51/2009 and subsequent amendments;
> II - Environmental Licence for Adherence and Commitment - LAC: Licence authorising the installation and operation of an activity or enterprise, by means of a declaration of adherence and commitment by the entrepreneur to the environmental criteria, preconditions, requirements and conditions established by the licensing authority, provided that the environmental impacts of the activity or enterprise, the environmental characteristics of the area of implementation and the conditions for its installation and operation are known in advance;
> III - Simplified Environmental Licence (LAS): approves the location and design of the undertaking, activity or work of a small size and/or with a low polluting/degrading potential, attesting to its environmental viability, establishing the basic requirements and conditions to be met, as well as authorising its installation and operation in accordance with the specifications contained in the approved applications, plans, programmes and/or projects, including the environmental control measures and other conditions determined by the licensing body;
> IV - Preliminary Licence (LP): granted at the preliminary planning stage of the undertaking or activity, approving its location and design, attesting to its environmental viability and establishing the basic requirements and conditions to be met in the next stages of its implementation;
> V - Installation Licence (LI): authorises the installation of the undertaking or activity in accordance with the specifications contained in the approved plans, programmes and projects, including the environmental control measures and other conditions, which constitute determining reasons;
> VI - Operating Licence (LO): authorises the operation of the activity or enterprise, after verification of effective compliance with the provisions of the previous licences, with the environmental control measures and conditions determined for the operation.

The release of these licences is linked to the classification of the biodigester's use and the size of the enterprise, factors that are defined in article 5 of the Resolution. The law establishes four types of biodigester, each with a specific use:

- TYPE I - Biodigester to be installed and licensed together with the main enterprise, for the purpose of treating effluents and/or organic waste generated exclusively in the same plant, in industrial, agricultural, sanitation and other enterprises.

- TYPE II - Specifically for the energy use of biogas for own consumption and/or distribution, from a biodigester that has been set up, licensed and is in operation, whether or not linked to a main enterprise. It also applies to the energetic utilisation of biogas generated in sanitary landfills that have already been set up and are in operation.
- TYPE III - Biodigester to be installed after the project has already been licensed, for the purpose of treating organic matter generated exclusively by the project, using the biogas for energy for own consumption and/or distribution.
- TYPE IV - Biodigester to be set up for the purpose of treating effluents and/or organic waste, including that of third parties, whether or not linked to another activity/enterprise that has already been licensed, with energy use of the biogas for own consumption and/or distribution.

The definition of the type of biodigester and its respective capacity is what will define the type of licence and the documents required for its release. An example of this is the provisions of Article 8, which requires the submission of an EIA/RIMA for projects generating more than 10MW.

> Art. 8 Electricity generation projects over 10 MW will be subject to the submission of an EIA/RIMA, as established in CONAMA Resolution 01/1986, regardless of the criteria established in Art. 6 of this Resolution.
>
> Art. 9 All the units and elements to be installed, from the biogas generation unit and the necessary transport structures to its energy utilisation, must be included in the project's licence.

From article 10 to article 24, the Resolution specifies the necessary documentation to be presented by the entrepreneur in order to obtain their Environmental Licence, renewal or waiver, according to the characteristics of the enterprise and the biodigester used.

Other issues are taken into account by the law for licensing purposes, such as the amount of polluting material produced or the places where this waste will be deposited.

It is important to highlight the provisions of article 32 of the Resolution, which states that "*for the agricultural use of digestate from a biodigestion unit that receives waste from cattle and pig farming enterprises, it must meet the criteria established by SEDEST Resolution No. 55 of 05.03.2019 and SEDEST Resolution No. 17 of 05.03.2020, for cattle farming enterprises and SEDEST Resolution No. 15 of 05 March 2020 for pig farming enterprises or others that may replace them*."

The text of the Resolution specifies all the requirements and obligations necessary for producers to obtain the licences they need.

It should be noted that the project must comply with the atmospheric emission limits set out in SEMA Resolution No. 016/2014.

> Section III - Atmospheric Emissions
>
> Art. 34 Atmospheric emissions must comply with the criteria and standards for atmospheric emissions established in SEMA Resolution No. 016/2014 or any other resolution that may replace it.

An important point to emphasise is the need to submit safety plans for the operation of biodigesters. Paraná already has specific legislation on the subject, the *IAT/SEDEST Technical Instruction "Safety Guide for the Implementation and Operation of Biodigesters",* which must be followed when applying for an Environmental Licence.

> Section IV - Risk and Safety Management
>
> Art. 35 Safety measures must be planned and implemented when operating biodigesters and handling biogas.
>
> Sole Paragraph. It is also recommended that additional safety measures be adopted, in accordance with the IAT/SEDEST Technical Instruction "Safety Guide for the Implementation and Operation of Biodigesters".

Likewise, hauliers transporting raw materials between the producer and the sorting or biodigestion plant must be duly licensed by the environmental agency.

> Art. 37 - The transport and agricultural use of solid waste from a biodigestion unit that receives waste from sanitation projects must meet the criteria established by SEMA Resolution 021/2009 or any other that may replace it, and the IAT must be requested to issue an Environmental Authorisation, in accordance with IAP Ordinance 212/2019 or any other that may replace it.

2.4 Technical and Locational Aspects

Also according to the journal "*Ensino de Ciências e Tecnologia em Revista*" (ENCITEC) from the postgraduate programme of the Universidade Regional Integrada do Alto Uruguai e das Missões - Santo Ângelo Campus (RS), pig production processes are characterised by a high level of environmental pollution, which can affect the quality of water and soil, generating environmental degradation.

Specifically, pig farms are recognised as activities with great polluting potential, in that they affect water resources and produce a significant quantity of liquid effluents that contain a high level of heavy metals.

Although the economic, social and cultural importance of pig farming is recognised, its production has a clear polluting potential due to the large volume of waste generated in small areas.

SEDEST Resolution 08/2021 also sets limits on the location of facilities, the emission of liquid effluents and the final destination of waste.

> Art. 39 The location of biodigesters must meet at least the following criteria:
>
> I - the development area must be located at a minimum distance from water bodies, so as not to reach permanent preservation areas, as established in the Forestry Code;
>
> II - the area of the enterprise, including storage, treatment and final disposal of waste, must be located at a minimum distance as established in the State Sanitary Code;
>
> III - the location of biodigester constructions must take into account the environmental conditions of the area and its surroundings, as well as the prevailing wind direction in the region, in order to prevent the spread of odours to nearby towns, population centres and homes.

In this sense, environmental licensing is the administrative procedure through which the environmental agency authorises the location, installation, expansion and operation of undertakings and activities that use environmental resources and will generate some kind of environmental degradation.

An important point to highlight is Article 43:

Art. 43: This Resolution must be reassessed every four (4) years or at any time when the environmental agency deems it necessary.

In other words, in 2025 (or earlier), this resolution could be modified, with the aim of improving its wording to meet the new needs of the state, in order to encourage the advancement of the biogas production chain, the attraction of investments in the area of renewable energies, and the technological, economic and socio-environmental development of strategic regions in the state of Paraná.

3. DECREE NO. 11.671/2014 - PARANÁ RENEWABLE ENERGY PROGRAMME) AND DECREE NO. 8.673/2018

DECREE 11.671/2014 (PARANÁ RENEWABLE ENERGY PROGRAMME) AND DECREE 8.673/2018

(https://www.legisweb.com.br/legislacao/?id=272690)

In 2014, the Paraná state government issued State Decree 11.671/2014 establishing the Renewable Energy Programme. The initiative created incentives for the generation of solar, wind, biomass, biogas or hydroelectric power in Hydroelectric Generating Plants (CGHs) and Small Hydroelectric Plants (PCHs), including environmental licensing procedures. Among other objectives, the decree sought to encourage the generation and consumption of electricity from renewable sources.

The decree established a number of incentives for renewable energy projects, among them:

- tax incentives;
- differentiated tax treatment;
- preference in the implementation of transmission line infrastructure;
- priority in environmental licensing and energy purchase processes; and
- specific lines of finance from state and regional financial institutions.

Decree 8.673/2018 changed some aspects of law 11.671/2014, broadening the scope of renewable energy initiatives. Generating plants (CGHs) and small hydroelectric plants (PCHs) were excluded from the document, which now reads as follows:

> Article 1, §1
> Renewable Energy is understood to mean electrical, thermal or liquid and/or gaseous fuel energy that comes from the use of organic waste from agriculture, urban areas, gastronomy, animal waste and slaughterhouse waste and its utilisation, human sewage, as well as electrical energy generated from the use of wind power and solar energy via photovoltaic panels."

The decree issued in 2014 was linked to the Smart Energy Paraná Project (PSE Paraná), which aimed to promote sustainable practices in order to consolidate the state's expertise in generating distributed energy from renewable energy sources, with tax incentives for specific sectors such as those below:

> Art. 2 In addition to the tax benefits already included in items 21-A and 70 of the RICMS, approved by Decree no. 6.080 , of 28 September 2012, other tax incentives or differentiated tax treatment may be granted in the event of investments in setting up an industrial establishment in Paraná territory, subject to the provisions and limits set out in Decree no. 630 , of 24 February 2011, which deals with the Paraná Competitive Programme, in relation to the following sectors:
>
> I - the production of parts, components and tools used in the generation of renewable energy;
>
> II - the production of material to be used as an input in the civil construction works required for renewable energy generation projects;
>
> III - the production of goods that form part of the connection and transmission infrastructure required by renewable energy generating projects for their interconnection with the National Interconnected System.

Also in 2018, the state of Paraná granted an exemption from the Tax on the Circulation of Goods and Services (ICMS) levied on the supply of electricity produced by distributed generation (mini and microgeneration), for a period of 48 months.

The programme is administered by TECPAR - Paraná Institute of Technology, with representatives from the State Secretariats.

> Art. 6 The Paraná Institute of Technology (TECPAR) is responsible for coordinating the Programme, which is the subject of this Decree, and is authorised to create a Working Group with the participation of representatives to be appointed by the Secretariats of Agriculture and Supply (SEAB), Finance (SEFA), Science, Technology and Higher Education (SETI), the Paraná Environmental Institute (IAP) and the Paraná Energy Company (COPEL).
>
> Sole Paragraph. Whenever necessary or convenient, the Paraná Institute of Technology - TECPAR may create Technical Committees to deal with specific issues, and the Bodies convened shall be responsible for appointing representatives to fulfil these functions.

4. STATE LAW NO. 20.607/2021 - STATE SOLID WASTE PLAN FOR THE STATE OF PARANÁ

LAW NO. 20.607/2021 - PARANÁ STATE SOLID WASTE PLAN (PERS/PR)

(*https://www.aen.pr.gov.br/sites/default/arquivos_restritos/files/migrados/1006lei20607.pdf*)

Law 20.607/2021, which establishes the **State Solid Waste Plan for the State of Paraná (PERS/PR),** is a public policy that determines strategies, guidelines and actions around the consumption, collection, recycling, treatment and disposal of solid waste in the state. Its fundamental premise is democratic management, which takes place through popular participation, involving associations representing society that took part in drawing up, monitoring and evaluating the plan.

The plan is managed by the State Secretariat for Sustainable Development and Tourism (Sedest) and the Water and Land Institute (IAT) is responsible for implementing the planned actions. PERS/PR establishes decisions and actions regarding waste management in the state and is based on the National Solid Waste Policy (PNRS), **Federal Law No. 12.305/2010**. All municipalities in the state are covered by PERS/PR, which encompasses 08 waste groups:

- urban solids (household, street cleaning and commercial);
- health;
- of the construction industry;
- transport services;
- mining;
- basic sanitation;
- industrial and
- agroforestry.

Based on the guidelines set out in Article 6 of the Plan, large generators are identified by the municipality and must become fully responsible for the proper environmental management of the waste generated, as well as the companies responsible for reverse logistics.

The Reverse Logistics Plan (PLR) is a requirement created by the law in its article 7, which deals with the guidelines of the State Solid Waste Policy and must be approved by Sedest so that the companies can implement it. companies obtain or renew environmental licences to carry out their activities. Logistics Reverse post-consumer packaging and the circular economy is strengthened by PERS/PR and concerns shared responsibility for the life cycle of products.

In addition, the plan prioritises the stages of non-generation, reduction, reuse and seeks to stimulate waste treatment models such as new mechanical, biological and thermal routes. Waste pickers' associations are valued by the law, as is the need for support from the public administration.

Other aspects provided for by the Law include:

- Provision that in environmental licensing procedures carried out in the state of Paraná, the entrepreneur becomes obliged to present the licensing body with data on the realisation of its reverse logistics;
- Adoption of mechanisms for total or partial exemption from the tax burden, a tax substitution regime and/or the establishment of a special deadline for the payment of state taxes relating to each solid waste economic chain

5. ADHESION OF THE STATE OF PARANÁ TO THE NEW CONFAZ AGREEMENTS

5.1 Paraná State adheres to new CONFAZ agreements

The state of Paraná has signed up to three agreements with the National Finance Policy Council (Confaz). These agreements make it possible to invest in energy generation using biogas.

Agreement 160/2023, which authorises the state to promote exemption from the Tax on Operations relating to the Circulation of Goods and Interstate and Intermunicipal Transport and Communication Services (ICMS) on operations with machinery, equipment, apparatus and components for generating electricity from biogas and biomethane.

Agreement 159/2023 authorises the granting of a presumed credit of 12% on the value of domestic purchases of biogas and biomethane.

Agreement 158/2023, which authorises the granting of a reduction in the ICMS tax base on internal exits with biogas and biomethane, so that the tax burden allows the application of a percentage of 12% on the value of the operation.

Under the new format of the Banco do Agricultor Paranaense, for renewable energy projects, the state of Paraná will be responsible for paying 100% of the interest rate for family farmers with an active Declaration of Aptitude to Pronaf (DAP) or enrolment in the Family Farming Register (CAF).

Civil works, the purchase of materials and equipment and the preparation of projects for the installation of biodigesters will also be covered in the event of investment by medium and large producers.

6. DRAFT DECREE REGULATING LAW 19.500/2018

6.1 Draft Decree Regulating Law 19.500/2018

6.1.1 General clarifications on the Draft

In 2020, **Biogás Brasil**, a project linked to the **Ministry of Science, Technology and Innovation (MCTI),** published, in agreement with the United Nations Industrial Development Organisation **(UNIDO),** the document entitled "**Evaluation of the Legal Framework for Biogas in Paraná (State Law 19.500/2018) and Proposal for Regulation - Final Report**", as part of the project "**Biogas Applications in Brazilian Agroindustry**" (GEF Biogás Brasil).

As well as being organised by the MCTI and UNIDO, the project also has funding from the **Global Environment Facility (GEF),** and its main executing body is the **International Renewable Energy Centre (CIBiogás)**. According to the document's introductory text, the work also involved the Paraná State Biogas and Biomethane Thematic Committee, which organised the text of the draft.

The document presents an assessment of State Law 19.500/2018 (State Biogas and Biomethane Policy), also known as the Paraná Biogas Legal Framework.

The study makes comparisons between the legislation of the other states of the Federation and the public policies adopted in three other countries. <u>The second part consists of a proposal to regulate the Legal Framework by means of a State Decree, based on an assessment of the effectiveness of all the articles of the law, the objectives of the original legislator and the sustainable development of the biogas chain</u>.

The Draft State Decree proposes regulating the legal framework for biogas by dividing it into 3 items:

- Environment and Health Licences;
- Promotion;
- Technological innovation.

In addition to regulating Law 19.500/2018, the draft proposes changes to Decree 6.434/2017, which deals with the Paraná Competitive Programme, and Decree 7.871/2017, which approves the Regulation of Tax on Operations Relating to the Circulation of Goods and on the Provision of Interstate and Intermunicipal Transport and Communication Services in the State of Paraná - RICMS/PR.

6.1.2 The Text of the Draft

In article 1, the draft suggests that the state decree should contain the requirements that companies wishing to qualify for technological innovation must fulfil.

> **Art. 1 In order for ventures and productive arrangements that fall under the provisions dealt with in Law 19.500, of 21 May 2018, including in the form of consortium, condominium, cooperative and public-private partnership, to be considered technological innovation companies, as** referred to in Law 17.314 of 24 September 2012, and may benefit from the **granting of tax incentives, financial resources, economic subsidies, materials or infrastructure,** to be adjusted in terms of differentiated tax regimes, special transfer regimes, assignment and use of tax credits, partnerships, agreements or specific contracts, aimed at supporting research and development activities in the territory of Paraná, they **must comply with the requirements established in this decree**.

> Sole Paragraph. Regardless of whether they fall under the technological innovation or research and development conditions referred to in Article 7 of Law 19.500, of 21 May 2018, these enterprises and productive arrangements may also, provided the other requirements established in this decree are met, receive differentiated tax treatment and any other forms of promotion for the production and consumption of biogas and biomethane generated in the State of Paraná, as referred to in Article 6 of the same law.

The article stipulates the players in the biogas chain and highlights the technological innovation ventures created by Law 17.314/2012, which provides for measures to encourage innovation and scientific and technological research, innovation and technological autonomy in the economic and social environment in general, and in the productive environment in particular, of the State of Paraná, under the terms of articles 200 to 205 of the State Constitution.

Paragraph 1 guarantees that even companies that do not qualify as technological innovators will be able to access tax incentives and other resources to encourage and support agents in the biogas chain in the state, as long as they fulfil all the other requirements contained in the decree.

However, it is always important to be categorised as a technological innovation company, which will be the case with the Mele project, due to its high level of innovation and novelty.

The applicant company must submit a set of documents listed in Article 2 of the draft.

> Art. 2 The following documentary evidence, if applicable, must be included in the processes for applying for a framework carried out by the enterprises and productive arrangements dealt with in art. 1 of this provision:
>
> I - Environmental Management Plans, Sectoral Agreements or Terms of Commitment in the case of members of an integrated production chain, in accordance with the terms of Article 3 of Law No. 19,500 of 21 May 2018 and the terms of Federal Law No. 13,288 of 16 May 2016;
>
> II - Environmental licences for the operation of waste and effluent transfer and transport activities, the production of biogas, biomethane and the generation of electricity from biogas issued by the competent environmental and health authorities, in accordance with the provisions of art. 4 of Law no. 19.500, of 21 May 2018, in cases where the production of biogas takes place in locations other than those where the organic waste is generated;
>
> III - Inspection certificates issued by the Paraná State Military Police Fire Brigade when necessary, in accordance with Article 5 of Law No. 19,500 of 21 May 2018.
>
> Paragraph One. In order to encourage new projects, environmental licensing for activities involving the transfer and transport of waste and effluents, the production of biogas, biomethane and the generation of electricity from biogas will be carried out in a simplified manner and with priority, and may also be covered by the same environmental licence as the producer's main activity.

After listing the licences and certificates that must be obtained by the enterprise in Article 2, the first paragraph allows for activities that are ancillary to biogas production, such as the transfer and transport of waste, to be included in the same general licensing as the enterprise.

6.1.3 Changes to the Paraná Competitive Programme (Tax Incentives)

Next, article 3 proposed by the draft introduces changes to Decree 6.434/2017, which deals with the **Paraná Competitive Programme**, which is a public policy designed to attract new investments, generate jobs and income, as well as maintain business activities, jobs and economic sustainability, with a view to maintaining the competitiveness of Paraná companies through stimuli aimed at infrastructure, tax incentives, development and technical support.

> **Art. 3** The following changes have been made to Decree No. 6.434, of 16 March 2017:
>
> **I -** Paragraph 3 is added to Article 3 and Article 3b, with the following wording:
>
> **§ 3 -** the limit in § 2 does not apply to the biogas and biomethane production chain and other products and rights derived from the decomposition of organic matter (biodigestion), including for its participants, with specific state registrations being authorised for each of the participants operating companies or investors in any of the corporate and contractual arrangements provided for by law.
>
> **Art. 3b** The Programme also applies to any projects linked to the implementation and/or expansion of the Biogas and Biomethane Production Chain and other products and rights derived from the decomposition of organic matter (biodigestion) located in the State of Paraná.
>
> **Sole paragraph of Article 3b.** The production chain for biogas, biomethane and other products and rights derived from the decomposition of organic matter (biodigestion) is understood to be the set of activities and undertakings linked to each other by contractual relations and which form part of sectors of the economy that use, produce, generate, industrialise, distribute, provide services, transport or commercialise products and rights derived from biodigestion, including solid waste and effluents.

Article 3 of Decree 6.434/2017 establishes that the Paraná Competitivo programme applies to projects for setting up, expanding, diversifying or reactivating establishments, and paragraph 2 of this article stipulates that the amount of investment made by the enterprise must be at least R$3,600,000.00 (three million six hundred thousand reais). Article 3 of the draft suggests that the decree exclude the biogas chain from this limitation. Article 3B and its sole paragraph introduce members of the biogas chain to the possibility of enrolling in the Paraná Competitive Programme, with a proper legal definition of the concept of the biogas chain.

Article 7 of Decree 6.434/2017 lists the tax incentives of the Paraná Competitive Programme, including those relating to biogas.

> **Art. 7** The Programme's tax incentives consist of:
>
> (...)
>
> **V -** ICMS deferral on purchases of biogas and the respective equipment, parts and components used in its generation, transport, processing, storage, mixing and conversion into any products and by-products, such as biomethane, CO_2, electricity, thermal energy, digestate, biofertiliser and any of its physical-chemical components;
>
> **VI -** differentiated use and transfer of ICMS credits, accumulated and enabled in SISCREDI in the cases provided for in art. 47 of Decree 7,871/2017, for the preponderant acquisition of plants, equipment, engines, parts and other components of the Biogas and Biomethane chain and other products and rights derived from the decomposition of organic matter (biodigestion), as well as waterway, rail and road modes with their respective storage and distribution structures.

The draft includes an item referring to biogas among the tax benefits provided for in article 7 of the decree establishing the Paraná Competitive Programme.

In addition, it also allows members of the Biogas Chain who wish to belong to the Paraná Competitive Programme to use and transfer ICMS credits accumulated and enabled in the Credit Transfer and Use Control System (SISCREDI) within the possibilities listed in article 47 of Decree 7,871/2017, legislation that introduced changes to the RICMS/PR.

The proposal made in the draft also adds two sections (VI and VII) to the text of decree 6.434/2017, establishing rules on the differentiated tax treatment of biogas and other products derived from biodigestion, as well as their respective production chains.

This framework, according to the draft proposal in the new section VI, depends on the signing of a protocol of intentions, special regime or any other contractual form that allows the state of Paraná to control the objectives and conditions for granting certain differentiated tax treatments for the entry and exit of parts, components, fixed assets, materials used in construction work, organic waste of animal and vegetable origin, inputs, raw materials, intermediate products and others.

In section VII, the draft deals with the authorisation, assignment, transfer and control of ICMS credits in the Biogas and Biomethane production chain.

> SECTION VII
>
> QUALIFICATION, ASSIGNMENT, TRANSFERS AND CONTROL OF ICMS CREDITS IN THE BIOGAS AND BIOMETHANE PRODUCTION CHAIN
>
> Art. 11-D. The accumulated credit in a graphic account arising from ICMS levied at all previous stages of the biogas and biomethane production chain, up to twice the investment value of the implementation projects, will be eligible for qualification, assignment and transfer, provided that it is previously included in the policies to incentivise the sector, precision agriculture or technological innovation, expansion or diversification projects, for the purchase of goods and merchandise that will make up fixed assets for the production, generation and consumption of biogas, electricity and other products, services and gaseous fuels predominantly produced from the biodigestion process, as well as telephone towers aimed at expanding signal coverage in the countryside.
>
> First Paragraph - The right to transfer may be transferred to industrial or commercial establishments of the same owner, as well as to establishments of entities that are condominiums, consortiums, cooperatives or any other type of investor participants in activities carried out through condominiums, consortiums or cooperatives of the same owner, the chain of biogas, biomethane and other products and rights derived from the decomposition of organic matter.
>
> Second Paragraph - The procedures set out in the heading of this article are subject to the rules of this decree and compliance with the specific environmental standards laid down by the competent bodies.

The draft also proposes that the credits accumulated in the graphic account from the ICMS tax levied in the previous stages of the biogas and biomethane production chain be authorised up to a limit of 2 times the value of the project investment.

It also suggests that the right to transfer can be transferred to industrial or commercial establishments owned by the same holder or establishments owned by joint ventures, consortiums or co-operatives.

The draft state decree that will regulate Law No. 19,500/2018 also proposes, in its article 4, changes to the text of Decree No. 7871/2017, known as the ICMS Regulation.

> Art. 4 The following changes have been made to Decree No 7.871, of 29 September 2017:
>
> I - Article 51-A is added, with the following wording:

"Art. 51-A. By means of a special regime granted by the Secretary of State for Finance, additional limits of up to twice the amount invested by the taxpayer may be authorised for the transfer of accumulated credits resulting from the expressly authorised maintenance of tax credits relating to subsequent operations or services destined abroad, exempt or deferred, to establishments predominantly linked to the production chain of biogas, biomethane and other products and rights derived from the decomposition of organic matter, understood as the set of activities and undertakings linked to each other by contractual relations and which form part of sectors of the economy that use, produce, generate and industrialise, distribute, provide services, transport or commercialise products, physical-chemical components and rights derived from biodigestion, including solid waste and effluents, conditional on investments in projects to expand activities or create new businesses in Paraná, including the expansion of telecommunication signal coverage for, among other related activities, the promotion of precision agriculture with telemetry and other technologies aimed at enhancing Paraná's agribusiness.

§ Paragraph 1 Without prejudice to the procedures set out in the Paraná Competitive Programme, referred to in Decree 6.434/2017, when applying for the special regime, an action plan must be submitted to reduce the credit balance in the tax graphic account, to offset the establishment's own debts and to expand business with taxed products.

§ Paragraph 2 The special regime referred to in the caput shall comply with the following:

I - must be requested by means of a specific application or procedure made available by the State Department of Finance;

II - will be granted for a fixed term, and its renewal depends on the fulfilment of the terms of commitment undertaken and the annual rendering of accounts by means of an application or procedure made available by the Secretary of State for Finance;

III - does not apply to taxpayers who have debts with the State Treasury; and

IV - the procedure for transferring credits shall comply, where applicable, with the provisions of this Chapter."

The draft proposes in this article that establishments linked to the Biogas Production Chain may be authorised to receive additional limits of up to 2 times the amount invested by the taxpayer for the transfer of accumulated credits resulting from the expressly authorised maintenance of tax credits relating to subsequent transactions or services abroad, which are exempt or deferred.

ARTICLES OF ASSOCIATION MELE BIOGÁS SPE LTDA.

H2UPPP PROJECT - MELE BIOGAS GmbH

1 THE RULES OF THE SPECIAL PURPOSE COMPANY (SPE) IN THE CIVIL CODE

Art. 981. People who reciprocally undertake to contribute, with goods or services, to the exercise of an economic activity and to share the results among themselves, enter into a company contract.

Sole Paragraph. The activity may be restricted to carrying out one or more specific businesses.

Art. 997. A company is formed by means of a written contract, either private or public, which, in addition to the clauses stipulated by the parties, shall mention:

I - Name, nationality, marital status, profession and residence of the partners, if natural persons, and the business name or denomination, nationality and registered office of the partners, if legal entities;

II - Name, object, registered office and term of the company;

III - the company's capital, expressed in current currency, which may comprise any kind of assets that can be valued in money;

IV - the share of each partner in the share capital, and the method of realising it;

V - the instalments to which the partner is obliged, whose contribution consists of services;

VI - the natural persons responsible for managing the company, and their powers and duties;

VII - each partner's share of profits and losses;

VIII - whether or not the partners are subsidiarily liable for the company's obligations.

Art. 999. Amendments to the articles of association concerning the matters listed in article 997 require the consent of all the partners; the others may be decided by an absolute majority of votes, if the articles of association do not stipulate the need for a unanimous decision.

Art. 1.031. In cases where the company is wound up in relation to a shareholder, the value of his share, considered in terms of the amount actually paid in, shall be settled, unless otherwise provided by contract, on the basis of the company's assets at the date of the winding up, as verified in a specially drawn up balance sheet.

§ 1o The share capital shall be reduced accordingly, unless the other partners pay up the value of the share.

Art. 1.010. When, by law or by the articles of association, it is the shareholders' responsibility to decide on the company's business, decisions shall be taken by a majority of votes, counted according to the value of each one's shares.

Art. 1.060. The limited liability company is managed by one or more persons designated in the articles of association or in a separate act.

Art. 1.061. The appointment of non-shareholder directors shall depend on the approval of at least 2/3 (two thirds) of the shareholders, while the capital is not paid up, and on the approval of the holders of shares corresponding to more than half of the share capital, after the capital has been paid up.

Art. 1,063 The office of director ceases upon the removal of the incumbent at any time, or upon the expiry of the term if there is no reappointment, as established in the contract or in a separate act.

§ Paragraph 1 In the case of a shareholder appointed as a director in the articles of association, his dismissal shall only be effected by the approval of the holders of shares corresponding to more than half of the share capital, unless otherwise provided in the articles of association.

Art. 1.065. At the end of each financial year, an inventory, balance sheet and profit and loss account shall drawn up.

Art. 1.071. In addition to other matters indicated by law or in the articles of association, these are subject to resolution by the shareholders:

I - the approval of management accounts;

II - the appointment of directors, when made in a separate act;

III - the dismissal of directors;

IV - the method of their remuneration, if not established in the contract;

V - amending the articles of association;

VI - the incorporation, merger and dissolution of the company, or the cessation of the state of liquidation;

VII - the appointment and dismissal of liquidators and the judgement of their accounts;

VIII - the request for composition with creditors

1.2 Comparison Table Ltda./S.A.

Below is an overview of the differences between the LTDA and S.A. corporate models.

Tabela 0-1

Features	Joint Stock Company (S/A)	Limited company (LTDA)
Liability of partners or shareholders	Limited to the issue price of the shares acquired	Limited to the value of the shares
Minimum capital	Minimum share capital requirement	No minimum capital requirement
Transfer of shares and quotas	Facilitated through negotiation	Restricted, requires shareholder approval
Corporate governance	Requires bodies such as the Board of Directors and the Executive Board	Not required, but allowed if desired
Third-party participation	Facilitates fundraising on the stock market	Restricted, with shareholder control
Minimum number of members	At least two people.	Minimum of two partners

Dissolution and liquidation	Complex and involves regulatory bodies	More flexible and administrative
Share capital	Divided into shares	Divided into quotas
Administration	Managed by supervisory corporate bodies	Managed by the partners or an administrator
General meetings	Compulsory	At least one assembly or meeting of members must be held every year, unless all the members decide in writing to dispense with it.
Corporate Governance Bodies	Mandatory, including Board of Directors, Executive Board and Supervisory Board	Not compulsory
Publication of financial statements	Since 1 January 2022, there is no longer any need for printed publications in official vehicles, but for summary publications in newspapers with a wide circulation and on the internet.	Not obliged to disclose publicly
Sale of shares	Facilitated through the sale of shares	With contractual restrictions and shareholder approval
Compulsory company books	Compulsory accounting books: Accounting books, subscription of shares, Inventory, Entry and Exit of Goods, Calculation of ICMS, IPI.	Brazilian legislation does not specify a set of mandatory corporate books

2 MODEL ARTICLES OF ASSOCIATION FOR MELE BIOGÁS LTDA.

MELE BIOGÁS SPE LTDA
ARTICLES OF ASSOCIATION

The contracting parties to this instrument of incorporation of a Special Purpose Limited Liability Company are the named and qualified companies:

..........................LTDA., a legal entity governed by private law, registered with CNPJ No. ..../0001-..., with registered office at Rua ...., Paraná, Brazil, hereby represented in the form of its Articles of Association, by its undersigned representative(s), hereinafter referred to as the MANAGING PARTNER;

..........................LTDA., a legal entity governed by private law, registered with CNPJ No. ..../0001-..., with registered office at Rua ...., Paraná, Brazil, hereby represented in the form of its Articles of Association, by its undersigned representative(s);

resolve, by mutual agreement, to set up a Special Purpose Limited Company, and do so under the following terms and conditions:

FIRST CLAUSE
NAME AND REGISTERED OFFICE, JURISDICTION

The company is called MELE BIOGÁS SPE LTDA, and its registered office is at Rua ______________________________, in the district and city of Toledo, state of Paraná.

Sole Paragraph - The company may open, transfer, close down branch offices and even transfer its own head office, in accordance with its interests, to any part of Brazilian territory.

SECOND CLAUSE
CORPORATE PURPOSE

The company's corporate object and specific purpose will be the production of industrial gases and biofuels.

CNAE: 1932-2/00 - Manufacture of biofuels, except alcohol
Activities that can be carried out with this CNAE:

- the manufacture of biodiesel obtained from the transesterification of vegetable oils or animal fats the manufacture of other biofuels

CNAE 2014-2/00 - manufacture of industrial gases
Activities that can be carried out with this CNAE:

- the manufacture of industrial or medical gases, liquid or compressed:
- elemental gases (oxygen, nitrogen, hydrogen, etc.)
  - liquid or compressed air
- refrigerant gases
  - inert gases such as carbon dioxide
  - industrial gas mixtures
  - acetylene, etc.

Sole Paragraph - The company hereby incorporated shall have a term of existence of 30 years.

THIRD CLAUSE
ADMINISTRATION

The company, through all its partners, appoints as director Mr ___________________, legal representative of the MANAGING PARTNER, already qualified in the preamble of this document, to exercise the management of the company, who will individually sign for the company, with management powers to set the direction of the business inherent to the activity and exercise the acts necessary for its achievement and the regular operation of the company, especially before financial institutions and public bodies, in addition to representing the company, active and passive, judicially and extrajudicially.

Paragraph 1 - The company may appoint proxies to represent it before third parties, with defined powers and terms, which may be granted for a fixed term.

Paragraph 2 - The directors shall use the company name, but are prohibited from using it in operations unrelated to the company's purpose, such as guarantees, loans and similar transactions.

CLAUSE FOUR
SOCIAL CAPITAL

The share capital is R$ ________ (________________), divided into _______ (_______) shares with a unit value of R$ 1.00 (one real), fully paid up in local currency.

	QUANT. QUOTAS	VALUE	PART (%)

		R$	

First Paragraph - The liability of each shareholder is restricted to the value of their shares, but all shareholders are jointly and severally liable for the payment of the share capital.
Second Paragraph - The partners will not be subsidiarily liable for the company's obligations, as established in article 1054 with article 997, VIII, of the current Brazilian Civil Code.

CLAUSE FIVE
ASSIGNMENT OR TRANSFER OF SHARES

The transfer of shares between partners, as well as the transfer of shares to third parties who are not partners, by an inter vivos act, whether by onerous assignment, donation or by any other means, is subject to the prior agreement of the other partners.

Sole Paragraph - Without prejudice to the preceding clauses, shareholders are guaranteed equal conditions and price, as well as the right of first refusal vis-à-vis third parties for the acquisition of shares if put up for sale, formalising the relevant contractual amendment if their transfer takes place.

CLAUSE SIX
FINANCIAL YEAR AND PROFIT DISTRIBUTION

The financial year ends on 31 December of each year, when the company's General Balance Sheet and Profit and Loss Account will be drawn up, and it will be up to the Directors, by mutual agreement, to decide on the allocation of the results, incorporating them into the share capital, keeping them in Retained Earnings, or distributing them to the shareholders, in proportion to each one's share in the share capital.

CLAUSE SEVEN
GENERAL PROVISIONS OF THE SPECIFIC PURPOSE

The partners declare, for all legal purposes, that the management company, through its representatives, will be fully responsible for all the obligations assumed, for as long as they last, with no liability on the part of other partners, except for the payment of capital.

First Paragraph - In the event of any dissolution, bankruptcy or judicial or extrajudicial reorganisation process of any of the members of the Company, or if any of its members proves incapable of fulfilling its contractual obligations, the other members shall assume the responsibilities and commitments of said member, preventing any consequences or damage to the obligations assumed by the Company as a result of contracts, as well as any claims, complaints, lawsuits and/or appeals by virtue of such fact.

Second Paragraph - For the purposes of the internal distribution of services, results, revenues, profits, costs, expenses, fines and losses, the quotaholding Managing Partner shall be responsible for the administration and execution of the services covered by the articles of association.

Third Paragraph - At the end of the company's term, including extensions, a reserve will be set aside for the purpose of settling certain and uncertain debts comprising tax, social security, commercial, labour and other liabilities, which will be determined at the end of the company.

Paragraph Five - The partners, by mutual agreement, agree that the managing partner, through its representatives, will be responsible for keeping the books and documents for the legal term.

CLAUSE EIGHT
SUCCESSION

The impediment, insolvency or death of any of the partners shall not dissolve the company, which shall first follow the rules of Clause Five regarding pre-emption rights and assignment to third parties.

First Paragraph - In such cases and on the basis of the social affection existing between the partners, the successors to the shares of the impeded, insolvent or deceased partner shall be entitled to join the Company. However, in the event that the successors do not wish to join the company, the assets or losses of the former partner shall be drawn up on the basis of an extraordinary balance sheet as at the date of the event.

Second Paragraph - Said extraordinary balance sheet shall include all the rights and obligations of the Company, with its assets being valued at market value and its liabilities also valued in accordance with the conditions contracted with third parties and/or valued on the basis of laws that so require.

CLAUSE NINE
MEETING OF QUOTAHOLDERS

Corporate resolutions shall be taken at meetings of shareholders, chaired and secretaried by the shareholders present, who shall draw up the Minutes of the Meeting, the company being exempt from keeping and drawing up a Book of Minutes of Meetings.

Paragraph 1 - The call to the members' meeting shall be made in writing, with individual acknowledgement, dispensing with the formalities of publication of the notice, in accordance with the second paragraph of article 1072 of the current Brazilian Civil Code.
Second Paragraph - The meeting of shareholders shall be convened with the presence, on first call, of holders of at least ¾ (three quarters) of the share capital and, on second call, with any number.

Paragraph 3 - The company shall hold an annual meeting, within four months of the end of the financial year, with the aim of deciding on the Balance Sheet and the Profit and Loss Account for the year, the publication of the aforementioned Financial Statements being waived.

Fourth Paragraph - For all other matters subject to shareholder resolutions, the minimum quorums set out in article 1.076 of the current Brazilian Civil Code shall be observed.

TENTH CLAUSE
LEGAL IMPEDIMENTS

The partners and directors declare, under penalty of law, that they are not prevented from exercising the management of the company by special law or by virtue of a criminal conviction, under the terms of the first paragraph of article 1011 of the current Brazilian Civil Code.

ELEVENTH CLAUSE
EXCLUSION OF A SHAREHOLDER

By decision of an absolute majority of the shareholders, formalised in a contractual amendment, a shareholder who is putting the continuity of the company at risk due to acts of undeniable seriousness may be excluded from the company for just cause.

Sole Paragraph - Exclusion for just cause must be decided at a meeting specially convened for this purpose, with the accused shareholder being informed in good time to allow him/her to attend and exercise his/her right to defence.

TWELFTH CLAUSE
OMITTED CASES
Omissions will be resolved in accordance with the provisions of articles 1052 to 1087 of the current Brazilian Civil Code, as well as any subsequent legislation applicable to the matter.

THIRTEENTH CLAUSE
FORUM

The jurisdiction of the district of Toledo/PR is hereby elected for the resolution of any dispute arising from this instrument, waiving any other jurisdiction, however privileged it may be.

And, as they are in agreement, all the partners sign this in the presence of the witnesses indicated below.

Toledo, ____ of ________ of 2024.

SIGNATURES

LEGAL REGULATORY REPORT ON GREEN HYDROGEN IN PARANÁ

H2UPPP PROJECT - MELE BIOGAS GmbH

SIGLAS

ALEPA legislative Assembly of Paraná
BRDE Regional Bank for Economic and Social Development of the Far South
CGHydroelectric Generating Centres
National Confederation of Industry
CNTC National Transport Confederation
COMPAGÁS Companhia Paranaense de Gás
CONFAZ Fiscal Policy Council
COPEL Companhia Paranaense de Energia Elétrica
FDE Economic Development Fund
FIEP Federation of Industries of the State of Paraná
Greenhouse Gases
GHG Green House Gases
GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit
H2Hydrogen
H2VHydrogen Green
ICMS Tax on the Circulation of Goods and Services
IAPAR-EMATER Rural Development Institute of Paraná
IAT Water and Land Institute
IPR Institute of Petroleum and Natural Resources of PUC/RS
NAPI-H2New Research and Innovation Arrangement
Renova PR Paraná Rural Renewable Energy Programme
PP Progressive Party
PSB Brazilian Socialist Party
PSD Partido Social Democrático
PUC/RS Pontifical Catholic University of Rio Grande do Sul
SANEPAR Sanitation Company of the State of Paraná
SBCES Brazilian Emissions Trading System
SEAB Secretariat of Agriculture and Supply of the State of Paraná
SEDEST Secretariat for Sustainable Development of the State of Paraná
SEED Secretariat of Education of the State of Paraná
SEFA Secretariat of Finance of the State of Paraná
SEIC Secretariat of Industry, Trade and Services
SEIL Secretariat of Infrastructure and Logistics
SEMA Secretariat of the Environment of the State of Paraná
SEPL Secretariat of Planning of the State of Paraná
SETI Secretariat of Science, Technology and Higher Education of the State of Paraná
TECPAR Paraná Institute of Technology
UFPR Federal University of Paraná
Export Processing Zone

1. STATE RENEWABLE HYDROGEN POLICY - STATE LAW NO. 21.454/2023

PART 1 - ANALYSIS OF THE STATE RENEWABLE HYDROGEN POLICY (STATE LAW No. 21.454/2023)
(https://www.legislacao.pr.gov.br/legislacao/pesquisarAto.do?action=exibir&codAto=292383&indice=1&totalRegistros=1&dt=6.10.2023.15.58.58.964)

(https://opresenterural.com.br/projeto-do-hidrogenio-renovavel-vai-potencializar-uso-de-biogas-do-meio-rural-no-parana/)

1.1 General Aspects

The major challenge currently facing the energy sector is the combination of economic development and the decarbonisation process. In this scenario, the use of hydrogen plays a strategic role.

Hydrogen has a greater amount of energy per quantity of mass, with a calorific value three times greater than petrol, but obtaining the molecule from renewable energy sources is a challenge, considering the costs and technology of the process.

The state of Paraná is creating the conditions to strategically position itself in the national production of renewable hydrogen in Brazil. On 3 May 2023, Governor Carlos Massa Ratinho Junior announced a set of initiatives that will enable the creation of a policy to promote research and production of Green Hydrogen in the state. The measures were announced during the 1st Renewable Hydrogen (H2) Forum in Paraná, held at the Oscar Niemeyer Museum in Curitiba.

The Governor announced the following measures:

- Creation of the Green Energy Programme in the state;
- Tax exemption for the H2R production chain;
- Creation of credit lines worth R$500 million to promote activities in the state;
- Creation of the Descomplica H2R programme, which establishes parameters for environmental licensing of this energy model.

He also sanctioned the bill that proposed the creation of the State Renewable Hydrogen Policy, which became Law No. 21,454/2023, authored by deputies Maria Victoria (PP), Alexandre Curi (PSD) and Luís Raimundo Corti (PSB).

At the same event, technical-scientific cooperation was formalised between the State Secretariat for Science, Technology and Higher Education (SETI), the Araucária Foundation and the Paraná Institute of Technology (Tecpar) with the aim of developing research projects on renewable hydrogen.

Starting with this package of measures and working with various business segments, Paraná is seeking to create a safe and competitive environment for attracting investment in the sector, especially with the creation of the state's legal framework for Green Hydrogen, which will now be regulated by decree, increasing legal certainty for the sector and encouraging the attraction of investment for the state's technological and energy development.

1.2 Analysis of Law 21.454/2023

The law creating the State Renewable Hydrogen Policy, unanimously approved by the Paraná Legislative Assembly (ALEP), aims to increase the share of renewable hydrogen in the state's energy matrix, encouraging the use of this input in its many applications. The law also creates another benefit for rural areas, which is the supply by rural producers of biogas for the production of green hydrogen.

Under the law, the state can sign agreements with public and private institutions and fund research and projects aimed at the technological development and cost reduction of energy systems based on the use of renewable hydrogen.

The measure also provides for the training of human resources to design, install and maintain renewable hydrogen-based energy system projects and encourages the use of renewable hydrogen in public transport, industry and agriculture.

In addition to energy factors, the State Renewable Hydrogen Policy will generate environmental impacts that can be seen in the reduction of greenhouse gas emissions, in line with the guidelines for tackling climate change and using an economy characterised by low carbon emissions.

The participants in the renewable hydrogen production chain, according to the legislation, will have shared responsibility for environmental management.

1.3 Definitions

To begin with, the law stipulates the definitions of renewable hydrogen and its production chain. Establishing these definitions in law is necessary because it is on this basis that subsequent regulations on specific aspects of the matter will be guided.

The text of the Paraná law states:

> Art. 2 For the purposes of this Law, the following are considered:
> I - renewable hydrogen: an element obtained from renewable sources through a low carbon emission process;
> II - renewable hydrogen production chain: undertakings and productive arrangements linked to each other and forming part of sectors of the economy that provide services and use, produce, generate, industrialise, distribute, transport or market renewable hydrogen and products derived from its use, which necessarily include the search for carbon credits when the economic and financial viability of the certification process is proven.

The Paraná State Hydrogen Policy therefore establishes that the classification of hydrogen as renewable is based on the principle that the energy used to obtain it is also renewable, but admits that this process can make use of carbon emissions at tolerable levels.

Production processes using renewable resources are classified according to the raw material: biomass or water. Those that use biomass are divided into two subcategories: thermochemical and biological. Thermochemical involves pyrolysis, gasification, combustion and liquefaction of biomass, while the main biological processes are biophotolysis, fermentation in the dark and photofermentation.

The second category of renewable technologies involves the production of hydrogen from water through electrolysis, pyrolysis (thermolysis) and photolysis (photoelectrochemical decomposition) processes.

The concern to define these concepts in the text of the law is understandable because, according to data from the Institute of Petroleum and Natural Resources at PUC-RS (IPR)33 , it is estimated that 96 per cent of the world's current hydrogen production is via non-renewable and non-ecological routes. Only around 48 per cent of global hydrogen is produced from natural gas, 30 per cent from burning oil (mainly consumed in refineries) and 18 per cent from coal.

Also according to the IPR, so far only 4 per cent of the total volume is produced from electrolysis of water. In other words, the current global production of hydrogen from fossil sources emits around 830 million tonnes of CO2 per year, which corresponds to around 2% of the world's annual CO2 emissions. In order for hydrogen production in Paraná to meet the criteria established in documents to which Brazil is a signatory, such as the Paris Agreement, the stipulation of concepts in law is essential and could avoid interpretative issues that generate conflicts between the consequent regulations.

With regard to the certification of green hydrogen, it should be noted that the procedure is still recent and does not have international regulations. Even so, companies have taken initiatives. This was the case with TÜV Rheinland, which issued the first green hydrogen certificate in Brazil and South America in January 2023. The certificate was awarded to White Martins, a company that represents Linde in South America, the world leader in the production, processing, storage and distribution of hydrogen, and will become the first company to produce green hydrogen on an industrial scale in the country and South America. [34]

Based on a comprehensive overview of the production process, TÜV Rheinland reviews the data provided so that it is complete and consistent with established norms and standards. In this case, TUV Rheinland's latest "H2.21 Green and Low-Carbon Hydrogen Standard" was used as the basis for certification. It is based on the GHG Protocol as well as other applicable EN ISO standards. GHG emissions are assessed following the Cradle to X (Gate) concept, through emission scopes 1 & 2 and partly scope 3, which aims to verify that hydrogen is produced through electrolysis fuelled exclusively by renewable energy sources, such as solar or wind.

After a successful review and a thorough audit procedure, TÜV Rheinland issued the certificate. "As the green hydrogen certification process is relatively new and there are no internationally approved regulations, it was essential to communicate, document and understand the criteria, concepts and processes for success at all stages, which follow the requirements of the GHG protocol and EN ISO standards such as 14064, 14067 and 14040," explains Luiz Carvalho, New Business Manager at TÜV Rheinland for South America.
(*https://rmai.com.br/2023/01/12/tuv-rheinland-emite-o-primeiro-certificado-de-hidrogenio-verde-no-brasil/*)

1.4 Objectives

Article 3 of Law 21.454/2023 lists the main objectives of the State's Green Hydrogen Policy:

I - increase the share of renewable hydrogen in the state's energy matrix;

II - stimulate:

the use of renewable hydrogen in its various applications, particularly as an energy source and for the production of agricultural fertilisers;

33 https://www.pucrs.br/blog/hidrogenio-verde/

34 https://rmai.com.br/2023/01/12/tuv-rheinland-emite-o-primeiro-certificado-de-hidrogenio-verde-no-brasil/

technological development aimed at the production and application of renewable hydrogen, geared towards the rational use and protection of natural resources;

the development and training of productive, commercial and service sectors related to hydrogen-based energy systems;

III - contribute to reducing greenhouse gas emissions and, consequently, to tackling climate change in line with a low-carbon economy;

IV - to stimulate, support and promote the renewable hydrogen production chain in the state of Paraná;

V - establish rules, administrative instruments and incentives to help develop and foster the renewable hydrogen production chain;

VI - to increase the share of green hydrogen in the energy matrix on an economic, social and environmental basis;

VII - to promote incentives, supervision and support for the renewable hydrogen production chain in the state;

VIII - provide synergy between renewable energy generation sources;

IX - attract investment in infrastructure for the production, distribution and commercialisation of renewable hydrogen.

7.11.1.1 1.4..1 Comments on the Objectives of the State Green Hydrogen Policy

The need to expand hydrogen and include it in the energy mix is a strategic measure aimed at meeting the demand for the product, which is currently verifiable due to the global geopolitical realignment.

The composition of Paraná's energy matrix, which is mostly hydroelectric, also has enormous potential in the area of biomass, due to its agro-industrial nature. This allows for a potential use of energy for the generation of renewable energy, and therefore within the guidelines that classify (and certify) green hydrogen.

This gives the state of Paraná a privileged position for the inclusion of renewable generation via green hydrogen, with great international potential, as well as for supplying the domestic market in Paraná and Brazil in its energy transition. The diversification of the energy matrix is a strategic and relevant long-term issue.

Therefore, *increasing the share of renewable hydrogen in the state's energy matrix and encouraging its use, especially as an energy source and in the production of agricultural fertilisers,* is strategically appropriate given the state's energy potential and the large arable area in Paraná, which is heavy in agricultural fertiliser consumption. (art. 3, I and II a)

Likewise, the technological development of this material as well as the development and training of productive, commercial and service sectors related to hydrogen-based energy systems are also among the activities that the law aims to stimulate.

In May 2023, the Government of Paraná announced the creation of its New Research and Innovation Arrangement (NAPI-H2), a research institute aimed at promoting research into the production of green hydrogen (H2V), with resources of around R$3 million.

The project is a partnership with the Araucária Foundation and the Federal University of Paraná, and involves the collaboration of five other universities in the state, 13 laboratories and 20 researchers. It is expected to last 36 months. This measure aims to give practical effect to *technological development aimed at production; and the development and training of productive, commercial and service sectors related to hydrogen-based energy systems, enabling the start of the construction of a technological base aimed at the hydrogen production chain. (art. 3, II b, c)*

Another factor that received focus in the text of the law was the reduction of greenhouse gas (GHG) emissions in order to tackle climate change. H2 stands out as a raw material for decarbonised industrial products and for use in highly polluting sectors such as the transport sector, reinforcing the prioritisation of reducing greenhouse gas (GHG) emissions. (art. 3, I and II a)

Having as one of the objectives of the State Green Hydrogen Policy to contribute to reducing greenhouse gas emissions and, consequently, to tackling climate change in line with a low-carbon economy (art. 3, III), is an important insertion in the text of the Law, especially at a time when Bill 414/2022, which establishes the legal framework for the Brazilian Emissions Trading System (SBCE), has been approved by the Federal Senate and will apparently be voted on later this year.

The hydrogen production chain, together with that of biofuels in Brazil, which involves ethanol and biogas, together with solar and wind generation capacity, provides great potential for the growth of green fuels, and is even seen as an opportunity for the reindustrialisation of Brazil, a proposal defended by CNI - the National Confederation of Industry and ABEEÓLICA - the Brazilian Wind Energy Association, which in 2021 was renamed ABEEÓLICA - the Brazilian Wind Energy and New Technologies Association.

Therefore, ***stimulating, supporting and fostering*** *the renewable hydrogen production chain in the state of Paraná* (art. 3, IV and VII) is an objective that must be accompanied by an industrial and technological incentive policy, facilitating *the* entry of new green technologies, machinery and equipment, technical cooperation agreements, incentives for production and the acquisition of inputs, tariff exemptions, support for the state's logistics infrastructure and other measures that will enable this new production chain to mature.

This process could also make use of the existing ethanol and biogas infrastructure to transport the hydrogen, and on the financial side, agricultural investment funds could be partners in guaranteeing the economic viability of hydrogen projects. The text of the State Law also provides for the establishment of rules, administrative instruments and incentives to help develop and foster the renewable hydrogen production chain (art. 3, V).

Another issue is the relationship between renewable energy sources. One of the aims of the law is to provide synergy between renewable energy generation models and hydrogen production (art. 3, VIII).

This synergy can be realised through hybrid energy systems. These are projects that plan to integrate energy generation sources and/or storage sources with batteries. This combination of sources, ranging from solar-wind, battery-wind or battery-solar, can be an industrial arrangement capable of guaranteeing constant production, storage or the temporary exchange of sources in situations of greater energy demand.

Sources such as wind and solar power are intermittent, i.e. they don't generate energy 24 hours a day. For constant and predictable production, it is necessary to combine these sources or use batteries to guarantee the energy supply.

Finally, ***attracting investment** in infrastructure for the production, distribution and commercialisation of renewable hydrogen* (art. 3, IX) is an objective that will depend on the development of this whole context provided for in the regulatory framework, and support for the growth and consolidation of a hydrogen chain capable of meeting market demands, especially the international market.

1.5 Actions

The realisation of the objectives set out in Article 3 depends on the formulation of actions by the Government, which are listed in the text of Article 4 of Law No. 21,454/2023.

I - to carry out studies and establish targets, standards, programmes, plans and procedures aimed at increasing the share of hydrogen energy in the state's energy matrix;

II - carry out studies:

to draw up tax and credit instruments to encourage the production and purchase of equipment and materials used in hydrogen production and application systems;

to allocate financial resources in the budget legislation to fund activities, programmes and projects aimed at the objectives of this campaign;

III - sign agreements with public and private institutions and finance research and projects aimed at:

the technological development and cost reduction of renewable hydrogen-based energy systems;
training human resources to design, install and maintain renewable hydrogen energy system projects;

IV - encourage the use of renewable hydrogen in public transport, industry and agriculture;
V - to promote studies in a regulatory sandbox, to develop production plants and services for low-carbon hydrogen, to implement technological solutions and innovations.

Carrying out studies, as well as standards, programmes, targets and procedures is the first action envisaged in the article aimed at encouraging an increase in the share of green hydrogen energy in the state's energy matrix. The recently created New Research and Innovation Arrangement (NAPI-H2), a research institute aimed at promoting research into the production of green hydrogen (H2V), is an important vehicle for carrying out these actions.

According to information from the **State Secretariat for Science, Technology and Higher Education,** the **general objective of NAPI-H2 is to** structure the creation of a research and innovation network in the area of renewable low-carbon hydrogen in Paraná, seeking to articulate actions that involve public and private institutions, in order to mainly boost the development of technologies, the provision of services and the training of specialised human resources.
Among the studies envisaged by the law are those to **draw up tax and credit instruments** to incentivise the production and purchase of equipment and materials used in hydrogen production and application systems.

This action could be achieved by allocating financial resources in the budget legislation to fund activities, programmes and projects in the green hydrogen production chain; and by drawing up tax incentives, which could take the form of ICMS exemptions via CONFAZ or the State Treasury, for all commercial activities in the production chain; support for the creation of Export Processing Zones (EPZs) within the state; and other incentives and exemptions.

Still within this perspective, the text of the Law stipulates that the Government may sign agreements with public and private institutions to finance research and projects aimed at technological development and cost reduction of renewable hydrogen-based energy systems and the training of human resources for the preparation, installation and maintenance of renewable hydrogen-based energy system projects;

The law refers specifically to the use of hydrogen in certain sectors of society, such as **public transport, industry and agriculture**.

As far as the transport sector is concerned, there is a trend towards Green Hydrogen becoming the most common fuel, given its zero carbon emissions. This is becoming a reality with the research and testing of green H2 as a fuel for motor vehicles, which is in full swing by the industries in the sector. When vehicles are fuelled with green hydrogen, the pollution is considerably less than that produced by diesel. This difference has been verified in 03 types of vehicles such as 12 tonne and 40 tonne trucks, as well as in urban buses.

According to data provided by the National Transport Confederation (CNT), "the reductions in GHG emissions are 87%, 85% and 89% respectively in relation to the same vehicles tested with diesel mixed with 7% biodiesel[35] . Some lorry and bus models already have on-board technology to be fuelled with H2, but there is still a lack of financial incentives to make this alternative more accessible, as well as the need to improve the infrastructure of filling stations."

The McKinsey Institute[36] points out that hydrogen could be used as a fuel for passenger vehicles; for long-distance rail freight; it could produce ammonia or methanol for bulk carriers and container ships; for road freight (medium and heavy trucks) and for mining trucks.

[35] https://cnt.org.br/agencia-cnt/cnt-lanca-publicacao-sobre-combustivel-renovavel-para-a-descarbonizao-do-transporte

[36] https://www.mckinsey.com/br/our-insights/hidrogenio-verde-uma-oportunidade-de-geracao-de-riqueza-com-sustentabilidade-para-o-brasil-e-o-mundo

According to McKinsey, there are three models for the **industrial energy use of hydrogen:**

- Hydrogen for medium and high-grade heating. A process in which hydrogen generates medium-grade (between 277°C and 650°C) or high-grade (over 650°C) industrial heat, used by the pulp and paper, cement and steel industries.
- Hydrogen for combined cycle turbines. In this case, hydrogen can be used as a single fuel or mixed with natural gas in combined cycle gas turbines for power generation.
- Hydrogen for blending with natural gas. In this situation, hydrogen is mixed in low proportions with natural gas in the gas distribution network.

In the agricultural sector, the state of Paraná has enormous biomass potential, which can be used as a natural input for the production of green hydrogen. This is an intelligent solution not only from an energy point of view, but also from an environmental point of view, as it makes it possible to put organic waste from agricultural production to an environmentally appropriate use. This is one of the key points of the Mele Biogás GmbH project, because as well as being innovative from a technological and scientific point of view, it also has a major environmental and social impact on the Toledo region, since it solves the environmental problem of the proper disposal of pig farming waste in the region.

The latest action by the government to promote the State's Green Hydrogen Policy opens up space for the implementation of a **regulatory sandbox**, i.e. a controlled and safe testing regime in which innovative companies can experiment with their products, services or business models without being subject to all the existing regulatory standards.

The model applied to hydrogen production in Paraná would serve the purpose of developing production plants and services for low-carbon hydrogen, with the aim of enabling the implementation of technological solutions for the development of a production chain in the sector.

1.6 Shared Environmental Responsibility

The State Hydrogen Policy provides for the shared and joint responsibility of the participants in the renewable hydrogen production chain and the production chains integrated with it with regard to environmental management.

> **Art. 5.** Participants in the renewable hydrogen production chain and production chains integrated with it will have shared and joint responsibility for environmental management, in line with the State Solid Waste Plan - Law No. 20,607, of 10 June 2021.

The concept of **shared responsibility** in environmental matters **derives from Law 12.305/10, which instituted the National Solid Waste Policy,** and which was followed by the State Policy through Law 20.607/2021. This responsibility means that everyone who is part of the chain is responsible for the life cycle of products, from their entry into the economic system to their return to the environment. The final destination of waste is guided by the so-called reverse logistics, which aims to structure channels for collecting waste so that it receives appropriate treatment before being returned to the environment.

1.7 Environmental and Safety Licensing

Regarding **environmental licensing** for renewable hydrogen activities, the state government announced the creation of the **Descomplica H2R** programme, which will be responsible for establishing the criteria and guidelines for issuing hydrogen production licences.

> **Art. 6** Activities involving the production, processing, storage, transport and generation of electricity from renewable hydrogen will be subject to environmental licensing, according to their polluting potential, under the terms of the applicable federal and state legislation.

The rule also stipulates that the entire process must be subject to the provisions of federal and state legislation on security issues.

> **Art. 7** Renewable hydrogen production, processing, storage and transport operations will be subject to the fire safety standards, among others, provided for in federal and state legislation.

1.8 The Decree Regulating Law 21.454/2023

Recently, on 25.09.2023, the **Parliamentary Front for Renewable Hydrogen of** the Chamber of Deputies of Paraná, whose coordinator is Congresswoman Maria Victoria, met to provide information on the progress of the decree that will regulate Law No. 12.454/2023. The structure of the decree was presented by Reginaldo Joaquim de Souza, a chemical engineer linked to SEDEST - the Secretariat for Sustainable Development, who gave an overview of the main topics of the new decree.

For the time being, the proposed structure of the Decree looks like this:

Chapter I - Initial Considerations
- Definitions
- Guidelines

Chapter II - Sustainability
- Energy Efficiency
- Energy Security
- Carbon emissions
- Circular Economy

Chapter III - The Production Chain
- Rural - SEAB
- Industrial - SEIC
- Infrastructure
- Production - SEAB and SANEPAR
- Storage - COMPAGÁS AND SANEPAR
- Transport - COMPAGÁS AND SEIL

Chapter IV - Research, Development and Innovation
- Training - SETI/FIEP/SEED
- Research - SETI/Araucária Foundation
- Innovation – SETI

Chapter V - Incentives
- Tax - SEFA
- Participation in the Energy Matrix - COPEL
- State Plan – SEPL

Chapter VI - Guarantees

Certification - TECPAR
Environmental Licensing - IAT/SEDEST
Inspection - IAT/Fire Brigade

Chapter VII - Governance

Leadership - SEPL
Creation of the Council
Creation of the Management Committee
Creation of Technical Chambers

The Thematic Chambers will be:

Sustainability and Carbon Technical Chamber
Technical Chamber of the Production Chain
RD&I Technical Chamber
Incentives Technical Chamber

1.9 Complementary Aspects

7.11.1.2 19.1.1 Paraná Rural Renewable Energy Programme (RenovaPR)

The Paraná Rural Renewable Energy Programme (RenovaPR) was regulated by Decree No. 7,872/2021, and created by Law No. 20,435/2020, which instituted the Paraná Rural Renewable Energy Programme.

The initiative is being coordinated by the Rural Development Institute of Paraná - Iapar-Emater (IDR-Paraná) to encourage the so-called distributed generation of electricity on rural properties using solar energy, biomass and that produced in Hydroelectric Generating Centres (CGH) and Micro Hydroelectric Generating Centres (MCGH).

As of June 2023, RenovaPR had released R$1.1 billion for 5,812 projects approved by IDR-Paraná. Of these projects, 5,768 are solar energy projects and 44 are biogas and biomethane projects. Since its creation, the programme has increased the number of rural properties generating their own energy from 5,558 to 25,684.

According to a report by the Rural Economy Department of the State Secretariat for Agriculture and Supply, RenovaPR accounts for almost 86 per cent of the funds financed by the Banco do Agricultor Paranaense, which offers producers reduced interest rates to invest in energy transformation.

The compensation assumed by the state is via the Economic Development Fund (FDE), which is linked to Fomento Paraná.

RenovaPR encourages all participants in the chain (producers, agro-industries and agricultural co-operatives) to install plants on their properties. The generation of thermal energy through electricity generated by the producers themselves will replace the demand for firewood. The programme will enable Paraná to become the most favourable Brazilian state for the production of green hydrogen. To this end, Paraná's biomass, particularly from animal protein production chains, is a significant and renewable source. Agro-industries and production chains for pigs, chickens and milk are promising because they are abundant in waste and residues which, as well as generating energy, could be used to produce hydrogen.

7.11.1.3 19.1.2 Promotion

For these actions to be realised, economic incentives are needed. In this regard, the **Paraná Development System, made up of Fomento Paraná and the Far South Regional Development Bank (BRDE),** will contribute R$500 million a year to the companies that make up the production chain. There will be R$300 million from the BRDE Sustainable Energy line and R$200 million from Fomento for investment and working capital projects.

Invest Paraná - a government business agency linked to SEIC - is an important instrument for supporting local companies and new investments. It accompanies the implementation of industrial projects in the state, with institutional support and through incentives, many of them of a tax nature, granted by the Treasury Department throughout all phases of the project with world-class services.

Invest Paraná recently signed a Memorandum of Understanding with Engie Brasil, a company from Santa Catarina that specialises in low-carbon energy production. In Brazil alone, the group operates 10 GW of 100% renewable energy. The agreement aims to realise projects for the large-scale production of green hydrogen in Paraná[37] .

The government has formed a group to work with the company, involving SEIC (through Invest Paraná), the Planning (SEAPL) and Agriculture and Supply (SEAB) departments, as well as the Paraná Energy (COPEL) and Sanitation (SANEPAR) companies.[38]

7.11.1.4 19.1.3 Research and Development

As far as research is concerned, projects involving teaching, technological development, production and industrial innovation in the field of low-carbon renewable hydrogen will be the subject of programmes developed through cooperation between entities such as SETI, UFPR, the Araucária Foundation and TECPAR, through NAPI-H2 (New Research and Innovation Arrangement).

7.11.1.5 19.1.4 State Economic Conditions

The state of Paraná is the largest producer of broiler chickens and the second largest producer of milk in Brazil, as well as having the second largest pig herd (5.3 million).

Paraná currently produces 270 million Nm^3/year of biogas (which represents 13.8 per cent of national production), with the potential to reach 1.3 billion Nm^3/year.

According to the Companhia Paranaense de Energia Elétrica (COPEL), the population of Paraná generates more than 10 million tonnes of Solid Urban Waste every day. This is an environmental liability that can be converted into electricity generation. Although the state has a world-record agricultural productivity market and extremely favourable climate and land conditions, the production of biomass for energy production is still timid. This factor can be reversed through initiatives such as the aforementioned Renova PR and the interest of organisations such as Copel itself.

The production of renewable hydrogen in Paraná is linked to the use of biomass, which can be a strong ally for

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[37] https://www.alemdaenergia.engie.com.br/engie-assina-acordo-com-invest-parana-para-desenvolver-projetos-de-hidrogenio-verde/

[38] https://www.aen.pr.gov.br/Noticia/Parana-fecha-acordo-com-empresa-referencia-em-energia-renovavel-para-desenvolver-mercado-de

Brazil in achieving the decarbonisation targets set out in the Paris Agreement during COP21 for the reduction of greenhouse gases (37% reduction by 2025 and 43% by 2030) and for increasing the share of renewable energy sources in the energy matrix.

LEGAL REGULATORY REPORT ON SAF IN BRAZIL

H2UPPP PROJECT - MELE BIOGAS GmbH

SIGLAS

Regulatory Impact Analysis

ANEEL Agência Nacional de Energia Elétrica

ANAC National Civil Aviation Agency

National Agency for Petroleum, Natural Gas and Biofuels

ASTM American Society for Testing and Materials

BNDES National Bank for Economic and Social Development

CAE Aviation Environmental Protection Committee (IACO)

CBIO Decarbonisation credits

CNPEC National Energy Policy Council

CONPET Programa Nacional da Racionalização do Uso dos Derivados do Petróleo e Gás Natural

CORSIA Carbon Offsetting and Reduction Scheme for International Aviation

EPE Empresa de Pesquisa Energética

FINEP Financier of Federal Government Projects

Greenhouse Gases

GIZ Deutsche Gesellschaft für Internationale Zusammenarbeit

GMTF Global Market Based Measures Task Force

IAT International Air Transport Association

IBAMA Brazilian Institute for the Environment and Renewable Natural Resources

ICAO International Civil Aviation Organisation

INMETRO National Institute of Metrology, Quality and Technology

MCTI Ministry of Science, Technology and Innovation

MME Ministry of Mines and Energy

PBE Vehicle Brazilian Labelling Programme

PNDV National Green Diesel Programme

PNPB National Programme for the Production and Use of Biodiesel

ProBio QAV National Sustainable Aviation Fuel Programme

PRO CONVE Programme for the Control of Air Pollution from Motor Vehicles

RBAC Brazilian Civil Aviation Regulations

RENOVABI National Biofuels Policy

SAF Sustainable Aviation Fuel

1. FUEL OF THE FUTURE BILL - FEDERAL EXECUTIVE BRANCH 2023

1.1 Fuel for the Future Bill - Federal Executive Branch

In September 2023, the Federal Executive presented[39] , the **Future Fuel Programme Bill,** which will be sent to the National Congress. The Bill includes a set of initiatives to promote sustainable low-carbon mobility, including aviation fuel, with the aim of increasing actions to meet international targets for reducing greenhouse gas (GHG) emissions.

The bill aims to create a public incentive policy for **advanced biofuels**, seeking to develop a domestic and export market for low-carbon fuels.

The project was drawn up jointly by the Ministries of Mines and Energy (MME), Development, Industry, Trade and Services (MDIC), Finance, and Ports and Airports. MME Minister Alexandre Silveira announced that there will be more than R$250 billion in investments[40] .

The Future Fuel Bill was drawn up with the broad participation of government representatives, industry, associations representing the various segments related to the fuel market and the scientific community.

The Bill aims to:

- the integration of the National Biofuels Policy (RenovaBio), the Rota 2030 - Mobility and Logistics Programme and the Brazilian Vehicle Labelling Programme (PBE Veicular);
- establishes the **National Sustainable Aviation Fuel Programme (ProBioQAV),** which aims to encourage the production and use of **Sustainable Aviation Fuel (SAF)**[41] ;
- creates the **regulatory framework for synthetic fuels in Brazil;**
- creates the National Green Diesel Programme (**PNDV**);
- raises the percentage of ethanol added to petrol to 30%; and
- proposes the regulatory framework for carbon dioxide capture and geological storage (CCUS) activities, which will also be regulated by the ANP.

Sustainable aviation now officially has a public policy through the **National Sustainable Aviation Fuel Programme (ProBioQAV).**

Under the new public policy, <u>airline operators are obliged to reduce carbon dioxide emissions by 1 per cent from 2027,</u> reaching a 10 per cent reduction by 2037, by gradually increasing the mixture of SAF with fossil aviation paraffin.

This obligation to reduce emissions and use SAF is also called an emissions **mandate.** By setting an emissions target - **and not a volume** target - the government leaves the **decision on the technological route to the market**, based on what makes the most economic sense for investors and *players in the* production chain,

[39] https://www.gov.br/planalto/pt-br/acompanhe-o-planalto/noticias/2023/09/lula-transicao-energetica-pode-tornar-o-brasil-o-que-o-oriente-medio-e-para-o-petroleo

[40] https://www.gov.br/planalto/pt-br/vice-presidencia/central-de-conteudo/noticias/combustivel-do-futuro-eleva-padroes-de-energia-limpa-e-descarbonizacao

[41] https://www.gov.br/mme/pt-br/assuntos/noticias/pl-do-combustivel-do-futuro-institui-programa-nacional-de-combustivel-sustentavel-de-aviacao

since the reduction in emissions varies according to **the technological route** and **the biomass** used to produce the SAF.

The bill will also create a **regulatory framework for synthetic fuels in Brazil**, with regulation assigned to the National Agency for Petroleum, Natural Gas and Biofuels (ANP). The idea is to create a regulatory

environment that allows for greater development and investment in the so-called "***e-Fuels***", which are being developed to replace fossil fuels, with the aim of improving the environmental performance of combustion engines, without the need to modify parts or components.

A policy for SAF in Brazil has long been a **demand of the airlines themselves, as they have already** begun testing the new product. The Bill has not yet been officially presented to the National Congress, but is in the final stages of being submitted to the Commission.

However, we will analyse points of the Bill later, through the draft made available by the Subcommittee of the **National Sustainable Aviation Fuel Programme (ProBioQAV).**

2. LAW NO. 14.248/2021 - THE NATIONAL BIOKEROSENE PROGRAMME

THE NATIONAL BIOKEROSENE PROGRAMME

(*https://in.gov.br/en/web/dou/-/lei-n-14.248-de-25-de-novembro-de-2021-362681641*)

Brazil already has a law that deals initially with aviation biofuel. In November 2021, Law 14.248/2021 was published, establishing the **National Biokerosene Programme, which** encourages research into and promotion of biomass-based energy production, with a view to the sustainability of Brazilian aviation.

With the aim of developing sustainable fuels for aviation, the law seeks to establish a policy to promote technological development for the production of biofuels, and to insert Brazil and the national aeronautical industry into the alternative fuels market, contributing to international commitments to reduce greenhouse gas emissions from the aviation sector.

The National Biokerosene Programme is part of the **Fuel for the Future Programme**, created by the **National Energy Policy Council (CNPE)** to increase the use of sustainable fuels in the national energy matrix.

Fuel for the Future has two objectives directly related to Law 14.248/2021:

- introducing the production of sustainable aviation fuels into the transport matrix; and
- the creation of incentives to invest resources in projects focused on developing the market for sustainable aviation fuels.

Among the barriers are technical-scientific-political bottlenecks relating to the availability of raw materials, industrial processing and integration with regionalised production chains.

The Fuel for the Future Programme created the **ProBioQAV thematic subcommittee**, which includes high-level institutions and representatives, contributing to broad social participation in the formulation of public policy.

The subcommittee seeks to create tax incentive mechanisms and structure project financing programmes for the production of sustainable aviation fuel, which will be supported by the National Biokerosene Programme Law.

Law 14.248/2021 is a short law. Article 2 of the Law sets out requirements and guidelines:

> Art. 2 The **National Biokerosene Programme** aims to develop clean technology in the production of biofuel.
>
> § Paragraph 1: The requirements for inclusion in the benefits of the National Biokerosene Programme are:
>
> I - the compatibility of biokerosene with current propulsion technologies, so that there is no need to alter existing engines, aircraft and distribution infrastructure;
>
> II - not jeopardising safety in the aviation system.
>
> § Paragraph 2 The **National Biokerosene Programme will cover the development of technology for mixing biokerosene with aviation paraffin of fossil origin in appropriate proportions,** as well as the development of technology that guarantees the total replacement of aviation paraffin of fossil origin.
>
> Art. 3 The research, production, commercialisation and energy use of biokerosene produced from biomass must be promoted by:
>
> I - the allocation of funds from federal development agencies and banks, under special conditions, for projects in this area;
>
> II - tax incentives granted by the Federal Government.

However, like most public policies relating to biofuels, with the exception of RenovaBio, the National Biokerosene Programme is a very recent initiative, still being created, and the initiatives that will develop the sector are still being drawn up, especially as it is a federal programme that has recently undergone a political transition.

Art. 4 The provisions of Law 9.478/97 apply to this Law.

Law 9.478/97 provides for national energy policy, activities relating to the oil monopoly, establishes the National Energy Policy Council and the National Petroleum Agency. It establishes the principles and objectives of national energy policy and creates the ANP, which is the regulatory agency that will issue the rules governing the **National Biokerosene Programme.**

Therefore, the ANP is the regulatory agency that will issue the norms and rules for the refining, transport, trade, import and export of aviation biofuel.

Law 9.478/97 already contains a chapter on biofuels with some provisions that are generally applicable to the market and are currently in force.

Art. 68-A. Any company or consortium of companies incorporated under Brazilian law with headquarters and administration in the country may obtain authorisation from the ANP to carry out economic activities in the biofuels industry.

§ 1o The authorisations referred to in the **heading are** intended to allow the exploitation of economic activities on a free enterprise basis and with ample competition, under the terms of the specific legislation.

§ 2o The authorisation referred to in the **heading** must take into account proof by the interested party, where applicable, of the conditions laid down in a specific law, in addition to the following, in accordance with regulations:

I - be constituted under Brazilian law, with headquarters and administration in the country;

~~II - be in good standing with the federal, state and municipal treasuries, as well as demonstrating good standing with the ANP; (Included by Law No. 12.490 of 2011)~~ (Repealed by Law No. 14.292 of 2022)

III - submit a basic project for the installation, in accordance with the norms and technical standards applicable to the activity;

IV - present an environmental licence, or another document that replaces it, issued by the competent body;

V - submit a security control project for the installations approved by the competent body;

VI - hold paid-up share capital or present other sufficient sources of funding for the venture.

§ 3o Authorisations can only be revoked at the request of the interested party themselves or when infractions punishable by such a penalty are committed, as provided for by law.

§ 4o Authorisation will be granted by the ANP within a period to be established in accordance with the regulations.

§ 5o Authorisation may not be granted if the interested party, in the five (5) years prior to the application, has had authorisation to carry out an activity regulated by the ANP revoked as a result of a penalty applied in an administrative process with a final decision.

§ 6o Agricultural production, the manufacture of agricultural and food products and the generation of electricity are not subject to regulation and authorisation by the ANP when they are linked to the establishment in which the biofuel production unit will be built, modified or expanded.

§ 7o The biofuel production unit that produces or commercialises electricity must comply with the rules and regulations established by the competent bodies and entities.

§ 8o The modification or expansion of facilities related to the exercise of economic activities in the biofuel industry is subject to prior approval by the ANP.

Therefore, several conclusions can be drawn from this article 68-A, as we conclude that:

The ANP is the agency that issues authorisations for economic activities in the biofuels industry;

- biofuel companies (*latu sensu, including new e-fuels)* can be set up under Brazilian law to produce biofuels in Brazil;
- the presentation of a basic project is a condition for authorisation by the ANP;
- the environmental licence must already have been issued by the competent body;
- the facilities safety control project approved by the competent body;
- compatible, paid-in share capital or presentation of funding sources;
- the manufacture of agricultural products and the generation of electricity from the biofuel production project are not subject to regulation and authorisation by the ANP;
- any expansion or modification to the biorefinery plant must be approved by the ANP.

Therefore, despite all the regulations still pending, both for *e-fuels* and hydrogen, it is possible to make progress on several stages that must be overcome for the project to materialise.

The potential is great, and much remains to be done. According to MME sources[42], Brazil has strategic conditions for the production of biofuels, and can serve both the domestic and international markets. Studies show the possibility of producing up to 9 billion litres of sustainable aviation fuel using sugar cane and wood waste, waste from the steel industry, animal protein processing and used cooking oil as raw materials.

3. CNPE RESOLUTION NO. 07/2021 - FUEL OF THE FUTURE PROGRAMME

CNPE RESOLUTION 07/2021 - FUEL FOR THE FUTURE PROGRAMME

(*https://www.gov.br/mme/pt-br/assuntos/conselhos-e-comites/cnpe/resolucoes-do-cnpe/resolucoes-2021*)

In the wake of Law 14.248/2021, which created the **National Biokerosene Programme** to encourage research and production of biomass-based energy for aviation fuel, the **National Energy Policy Council (CNPE) issued** CNPE Resolution 07/2021, which established the **Fuel for the Future Programme** and created the **Fuel for the Future Technical Committee**.

Article 1 establishes the programme and from the heading we can see that the Fuel for the Future Programme refers to all biofuels, not just aviation fuel.

> **Art. 1** Establish the Fuel for the Future Programme with the aim of proposing measures to increase the use of sustainable and low-carbon fuels, as well as national vehicle technology with a view to decarbonising the national transport energy matrix.

Article 3 creates the Fuel of the Future Technical Committee, which has the following objectives:

> I - to propose measures for integration between the National Biofuels Policy (RenovaBio), the National Biodiesel Production and Use Programme (PNPB), the Programme for the Control of Air Pollution from Motor Vehicles (Proconve), the Rota 2030 Programme, the Brazilian Vehicle Labelling Programme (PBE Veicular) and the National Programme for the Rationalisation of the Use of Petroleum Derivatives and Natural Gas (CONPET), among others;

[42] https://www.gov.br/mme/pt-br/assuntos/noticias/sancionada-lei-que-estabelece-o-programa-nacional-do-bioquerosene

II - to propose measures to improve fuel quality, with a view to promoting a reduction in the average carbon intensity of the fuel matrix and transport emissions and increasing energy efficiency;

III - to propose the methodology for evaluating the complete life cycle (from well to wheel) for the purposes of evaluating emissions from the various modes of transport, including emissions associated with the manufacture of vehicles;

IV - to propose studies to assess the possibility of bringing the reference fuels closer to the fuels actually used, taking into account the maintenance of the deadlines established by Proconve;

V - to propose actions to provide consumers with adequate information to help them make a conscious choice of vehicle and energy source, taking into account the life cycle of fuels;

VI - propose studies to expand the use of sustainable and low-carbon fuels, such as:

specifying high-octane, low-carbon fuels;
evaluation of available fuel cell technologies to guide research, development and innovation;
creation of green corridors for fuelling heavy vehicles powered by biomethane, liquefied natural gas, natural gas and others;
technical and economic conditions for large-scale production of second-generation ethanol;
the use of sustainable, low-carbon fuels for maritime transport;
introduction of sustainable aviation paraffin into the energy matrix (ProBioQAV);
use of carbon capture and storage technology associated with the production of sustainable, low-carbon fuels (ProBioCCS);
use of sustainable, low-carbon fuels in the diesel cycle; and
creating incentives for companies to invest resources in research, technological development and innovation projects focused on the themes covered by the Fuel for the Future Programme.

Sole Paragraph. In order to fulfil the objectives referred to in the heading, the CT-CF should preferably conduct its work with the participation of agents from the sector and other interested parties.

The Committee is coordinated by the Ministry of Mines and Energy, and is made up of representatives from the Civil House and 7 other Ministries, representatives from ANP, ANAC, EPE, the Brazilian Maritime Authority, IBAMA and INMETRO, as well as representatives from civil society who may be invited to take part in the subcommittees.

The **Fuel for the Future Technical Committee** had 360 days to study and present reports on the actions and initiatives that will guide public policy in the sector, with the ultimate aim of proposing the Bill, and also presented various studies, including the Report "Economic Analysis of Different SAF Production Routes"[43] , which had the support and participation of GIZ[44] , among other studies and analyses.

The provisions of CNPE Resolution 07/2021 - Fuel for the Future Programme and the ProBioQAV studies are the basis of the Bill presented by the current Federal Government.

[43] https://www.gov.br/mme/pt-br/assuntos/secretarias/petroleo-gas-natural-e-biocombustiveis/combustivel-do-futuro

[44] https://www.gov.br/mme/pt-br/programa-combustivel-do-futuro/analise-economica-diferentes-rotas-de-producao-de-saf.pdf/view

4. LAW NO. 11.097/2005 - INTRODUCING BIODIESEL INTO THE BRAZILIAN ENERGY MATRIX AND ANP RESOLUTION 842/2021

LAW NO. 11.097/2005 - INTRODUCTION OF BIODIESEL INTO THE BRAZILIAN ENERGY MATRIX
(https://www.planalto.gov.br/ccivil_03/_Ato2004-2006/2005/Lei/L11097.htm)

Law No. 11.097/2005 was the measure that introduced Biodiesel into the Brazilian Energy Matrix. It amends Law 9.478/97, introducing the following definitions:

Biofuel: fuel derived from renewable biomass for use in internal combustion engines or, according to regulations, for other types of energy generation, which can partially or totally replace fossil fuels.

Biodiesel: biofuel derived from renewable biomass for use in internal combustion engines with compression ignition or, according to regulations, for generating other types of energy, which can partially or totally replace fossil fuels.
The recent ANP Resolution NO. 842/2021 established the specification of green diesel, as well as the quality control obligations to be met by the economic agents that commercialise it in national territory.

According to Article 2 of the Resolution, the green diesel covered by the standard is that which can be produced from the following routes and raw materials:

> I - hydrotreatment of vegetable oil (in natura or residual), algae oil, microalgae oil, animal fat and biomass fatty acids, as well as hydrocarbons bioderived by Botryococcus braunii microalgae;
>
> II - synthesis gas from biomass via the Fischer-Tropsch process;
>
> III - fermentation of carbohydrates present in biomass;
>
> IV - oligomerisation of ethyl alcohol (ethanol) or isobutyl alcohol (isobutanol); and
>
> V - catalytic hydrothermolysis of vegetable oil (fresh or residual), algae oil, microalgae oil, animal fat and biomass fatty acids.

Paragraphs 1 and 2 make room for other technological routes to be assessed and authorised by the ANP.

> § Paragraph 1 The sale of green diesel produced by routes and raw materials other than those set out in items I to V of Article 2, and which meets the specification set out in the Annex, depends on prior assessment and authorisation by the ANP.
>
> § Paragraph 2 In the cases provided for in the previous paragraph, other parameters may be included in the specification provided for in the Annex, in order to guarantee the necessary quality of the product to be commercialised.

The Resolution includes other definitions such as sample, biomass, green diesel, quality certificate, producer, refinery and others. Registrations, licences and authorisations are governed by other rules that regulate the administrative-regulatory processes before the Regulatory Agency.

5. PROBIOQAV - NATIONAL SUSTAINABLE AVIATION FUEL PROGRAMME

PROBIOQAV - NATIONAL SUSTAINABLE AVIATION FUEL PROGRAMME
(https://www.gov.br/mme/pt-br/assuntos/secretarias/petroleo-gas-natural-e-biocombustiveis/combustivel-do-futuro/subcomites-1/probioqav)

5.1 The Saf

Sustainable aviation fuel, known as SAF (*Sustainable Aviation Fuel*), **is produced from organic waste** to replace fossil aviation fuel

As part of a global goal of zero pollutant emissions by 2050, its use will become even more essential from 2027, when aeroplanes will not be able to take off for international destinations without offsetting the carbon produced in operations.

This compensation can be done through the purchase of carbon credits or by supplying a mixture of SAF.

According to the **ICAO - International Civil Aviation Organisation,** there are more than 30 initiatives around the world being adopted or under development to increase SAF production, as well as more than 120 countries, including Brazil, which have voluntarily joined a carbon offsetting and reduction arrangement for international aviation, **CORSIA**.

It is estimated that the green fuel will have a demand of **20 million cubic metres per year** across the planet by 2030, according to the International Air Transport Association (IATA).

Sustainable aviation fuels have technological routes and specifications approved internationally by the American Society for Testing and Materials (ASTM) and in Brazil they must be approved by the National Petroleum, Natural Gas and Biofuels Agency (ANP).

5.2 The Probioqav Subcommittee

The ProBioQAV Subcommittee, which aims to propose guidelines for the introduction of sustainable aviation paraffin (SAF) into the energy matrix, listened to *stakeholders, held* a seminar with the BNDES on the subject, and called for social participation from interested parties and representatives of the sector in order to draw up the RIA - Regulatory Impact Analysis - studies.

Participants in the ProBioQAV Subcommittee:

- Airlines
- Airline Industry Associations
- Fuel and Biofuel Industry Associations
- Fuel and Biofuel Producers
- Aircraft Manufacturers
- Airport Industry Associations
- International Organisations
- Government bodies
- Teaching and Research Institutions
- Funding Institutions
- Energy Consultancies
- Regional, State and International Initiatives

The Subcommittee presented various technical documents with premises and suggestions, all of which have been presented and are pending the creation of laws, regulations, and the definition of criteria and mechanisms for the development of the sector45 .

Six thematic pillars were presented and 27 premises were listed to guide future regulations. The pillars are:

- Mandate (07 premises)
- Decarbonisation and Corsia targets (03 assumptions)
- Financing Projects and RD&I (05 premises)
- Taxation (04 premises)
- Quality and Certification (04 premises)
- Governance and Other Issues (04 premises)

A Draft Bill was presented, which brings definitions already established in CNPE Resolution 07/2021, but brings new features such as:

- Establishes the National Sustainable Aviation Fuel Programme - ProBioQAV
- The ANP will define the lifecycle values from well to flare for each SAF production route
- Mandatory minimum reduction of CO2 emissions by 1% for air operators on domestic flights from 1 January 2027
- ANAC will be in charge of verifying the calculation methodology for verifying the reduction of emissions associated with the use of sustainable aviation fuel and overseeing compliance by air operators
- Reciprocity for countries that oblige national airlines to use the SAF
- The conceptual definitions of Aviation Biokerosene and Sustainable Aviation Fuel (SAF)

Finally, Study 1 of ProBioQAV - MME and ProQR/GIZ: Governance and Public Policies to Incentivise Sustainable Aviation Fuel (SAF) was presented.

With the 2022 elections and the political transition in the federal government, public policies are undergoing changes and adaptations to the new government.

5.3 The Premises of the Probioqav Subcommittee

The Subcommittee defined 6 thematic pillars and 27 premises to get the aviation biofuels policy off the ground. Let's take a look at them:

- Mandate (07 premises)
- Establish emission reduction mandates for the airline industry
- Allow all technological routes approved by ASTM and ANP
- Allow different SAF levels in any part of the country
- Exempt international sections of international flights, respecting the reciprocity of international airline agreements
- Give the CNPE flexibility

[45] https://www.gov.br/mme/pt-br/assuntos/secretarias/petroleo-gas-natural-e-biocombustiveis/combustivel-do-futuro/subcomites-1/probioqav/documentos-do-subcomite-1

Making airports viable for the use of SAF, taking into account the development of SAF production and logistics chains, airport demand and the availability of raw materials.
Enabling the application of Book & Claim for specific cases:

- Decarbonisation and Corsia targets (03 assumptions)
- Assign CBIO purchase targets to aviation fuel distributors
- Evaluate the possibility of methodologically aligning Renovabio with Corsia for SAF
- Accounting for emission reductions only with SAF, whether domestic or imported.

- Financing Projects and RD&I (05 premises)
- Regulate art. 3, I of Law 14.248/2021 (federal promotion)
- Structuring financing lines for SAF through the BNDES
- Extend SAF incentives to Green Diesel, with a view to developing biorefineries
- Establish government guidelines for financing projects and RD&I
- Evaluate the structuring of a Guarantee Fund with the participation of the National Treasury for SAF investment projects
-
- Taxation (04 premises)
- Create tax classification for SAF (pure and blend)
- Define ICMS rules for SAF (pure and blended)
- Regulating art. 3, II of Law 14.248/2021 (PIS/COFINS)
- Assess the feasibility of encouraging the use of raw materials from family farms
-
- Quality and Certification (04 premises)
- All SAF must meet ASTM and ANP specifications
- Create incentives for the formation of a Network of Accredited Laboratories
- Establish Quality Audits and Certifications process
- Create SAF Quality Monitoring Programme
-
- Governance and Other Issues (04 premises)
- Insert definition of SAF in Law 9.478/1997
- Defining the responsibilities of CNPE, ANP and ANAC in SAF public policy
- Create incentives for SAF exports
- Debureaucratising and optimising environmental licensing applications for SAF

6. CORSIA IN BRAZIL AND ANP RESOLUTION NO. 856/2021

6.1 CORSIA IN BRAZIL AND ANP RESOLUTION NO. 8562021

CORSIA - Carbon Offsetting and Reduction Scheme for International Aviation is the ICAO - International Civil Aviation Organisation programme for reducing and offsetting CO_2 emissions from international flights[46] .

The programme aims to guarantee aviation's participation in the fight against climate change, through the use of the SAF and the acquisition of carbon credits. In general, the credits are issued by other sectors of the economy that have more efficient and cheaper alternatives for reducing their CO_2 emissions than the aviation sector itself.

[46] https://www.icao.int/environmental-protection/CORSIA/pages/default.aspx

Brazil is a signatory to CORSIA and began the process of monitoring the international CO_2 emissions of its air operators in January 2019.

ANAC is the body responsible for implementing CORSIA and supervising air operators[47] , and ANAC Resolution 496 of 28 November 2018 contains the guidelines that Brazilian air operators must follow in order to comply with the programme's requirements.

From 2027 onwards, the international emissions of Brazilian operators, above the levels observed in the average for the 2019-2020 biennium, must be offset through the acquisition of carbon credits or through the use of CORSIA-eligible fuels, especially sustainable aviation fuels.

There is a discussion forum for the control of CO emissions$_2$ in which ANAC participates, which is the IACO Committee for Aviation Environmental Protection (CAEP).

There are several sub-groups within the CAEP structure, including Working Group 4 - CORSIA (WG4). WG4 was set up to continue the work of the Global Market Based Measures Task Force (GMTF). The results of the discussions are evaluated and then incorporated into Volume IV of Annex 16 to the Chicago Convention, and subsequently incorporated into ANAC regulations, through the Brazilian Civil Aviation Regulations (RBAC) No. 38.

The ANP has been evolving its resolutions on the subject up to the current standard, which is ANP Resolution No. 856/2021

ANP Resolution No. 856/2021 - Establishes the specifications for JET A and JET A-1 aviation paraffin, alternative aviation paraffin and aviation paraffin C (JET C), as well as the quality control obligations to be met by economic agents who sell these products in Brazil. The alternative aviation paraffins covered by the Resolution are:

I - hydroprocessed paraffinic paraffin synthesised by Fischer-Tropsch (SPK-FT);

II - paraffinic paraffin synthesised with hydroprocessed fatty acids and esters (SPK-HEFA);

III - paraffinic paraffin synthesised with aromatics (SPK/A);

IV - paraffinic paraffin synthesised with alcohol (SPK-ATJ);

V - isoparaffins synthesised from fermented and hydroprocessed sugars (SIP);

VI - catalytic hydrothermolysis paraffin (CHJ); and

VII - paraffinic paraffin synthesised from bioderived hydrocarbons, fatty acids and hydroprocessed esters (SPK-HC-HEFA).

The Resolution contains other definitions such as sample, quality bulletin, quality certificate, producer, distributor and others. Registrations, licences and authorisations are governed by other rules that regulate the administrative-regulatory processes before the Regulatory Agency.

[47] https://www.gov.br/anac/pt-br/assuntos/meio-ambiente/corsia

LEGAL REGULATORY REPORT ON GREEN HYDROGEN IN BRAZIL

SIGLAS

ABEEOLICA Brazilian Association of Wind Energy and New Technologies
ABIOGAS Brazilian Biogas Association
Brazilian Association of Technical Standards
ABSOLARA Brazilian Photovoltaic Solar Energy Association
AFOFAfficial Financial Development Agency
AFRMMA Freight Charge for the Renewal of the Merchant Navy
AHK RioGermany-Brazil Chamber of Commerce and Industry of Rio de Janeiro
ANAA National Water and Sanitation Agency
ANEEL Agência Nacional de Energia Elétrica
National Petroleum and Biofuels Agency
ANTAQ National Waterway Transport Agency
IDB Inter-American Development Bank
BNDES National Bank for Economic and Social Development
CBIO Decarbonisation Credit of the National Biofuel Policy - RenovaBio
CCC Fuel Consumption Account
CCEEC - Electricity Commercialisation Chamber
CDEC Energy Development Account
CEHVC Special Commission to Debate Public Policies on Green Hydrogen
CNPEC National Energy Research Council
CGHBC Low Carbon Hydrogen Steering Committee
COFIN Federal Social Security Contribution
Coges-PNH2C Management Board of the National Hydrogen Programme
COMPAGÁS Companhia Paranaense de Gás
COPEL Companhia Paranaense de Energia Elétrica
Science Technology & Innovation
COP Conference of the Parties to the United Nations Framework on Climate Change
CSL Social Contribution on Net Profit
DIP Declaration of Prior Interference
Risk Analysis Study
FINEP Financier of Federal Government Projects
FNMC National Climate Change Fund
Greenhouse Gases
GIZDeutsche Gesellschaft für Internationale Zusammenarbeit
H2RRenewable Hydrogen
H2VHydrogen Green
IBAMA Brazilian Institute for the Environment and Renewable Natural Resources
IBH2 Brazilian Hydrogen Initiative
ICMS Tax on the Circulation of Goods and Services
III Import Tax
IPCC Intergovernmental Panel on Climate Change of the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO)
IPII tax on Industrialised Products
IRPJ Corporate Income Tax
ISSQNI Tax on Services of Any Kind
I-REC Renewable Energy Certificate

MEC Ministry of Education
MCTI Ministry of Science, Technology and Innovation
MDIC Ministry of Development, Industry, Trade and Services
MME Ministry of Mines and Energy
Emergency Action Plan
Research , Development and Innovation
Risk Management Plan
PHBC Low Carbon Hydrogen Development Programme
PIS Social Integration Programme
PNH2 National Hydrogen Plan
PNMC National Policy on Climate Change
PL Draft Law
PRO HIDROVERDENational Green Hydrogen Programme
PROINFA Programme to Encourage Alternative Sources
REID Special Incentive Scheme for Infrastructure Development
REINTEGRA Regime Especial de Reintegração de Valores Tributários para Empresas Exportadoras
RENOVABI National Biofuels Policy
Joint Stock Company
SBCES Brazilian Emissions Trading System
Special Purpose Entity
National Interconnected System
SisH2-MCTIS Brazilian Hydrogen Laboratory System
SISCLIMA System for Climate Monitoring
SUDENE Superintendence for the Development of the Northeast
TUST Tarifa de Uso do Sistema de Transmissão de Energia Elétrica (Tariff for the Use of the Electricity Transmission System)
Export Processing Zones

THE NATIONAL HYDROGEN PLAN (PNH2) - MINISTRY OF MINES AND ENERGY

GENERAL ASPECTS OF THE HYDROGEN MARKET

Hydrogen is recognised as the lightest element in the universe and has a high energy density. The so-called "green hydrogen" is found in combinations with other elements such as oxygen, in a mixture that results in water. Its extraction, in the case of water, is done through electrolysis, a complex process that, despite its high cost, has come to be seen as the new frontier for a viable alternative in the energy transition.

Hydrogen is already regulated in many countries around the world. Hydrogen-powered heavy-duty vehicles already ply the streets in countries such as China, South Korea, the United States, Japan and Germany, among others. Of all the countries that are emerging as significant players on the green hydrogen production and distribution scene, Brazil is favoured by its abundance of natural resources and great solar, hydroelectric and wind potential, which are essential for the production of green hydrogen.

Green hydrogen (H2V) is produced from renewable energies and its production through the electrolysis of water requires high doses of energy to break down water into oxygen and hydrogen, without any carbon emissions (Zero Carbon). In addition to green hydrogen, there are five other types of hydrogen:

- Brown (which uses coal as a fuel source and gasification as a process);
- Grey (which uses natural gas and steam reforming as a process);
- Turquoise (which uses natural gas and pyrolysis as a process);
- Blue (natural gas and uses CO2 seizure as a process);
- Yellow (electricity grid and uses electrolysis as a process);
- Pink (heat and uses nuclear energy associated with electrolysis as a process).
-

The trend is for the consolidation of new technologies to gradually reduce the value of fees and, consequently, the risk of investment. According to a study published in partnership between the Heinrich Böll Foundation and Brot für die Welt48 , the countries best suited to producing green hydrogen are Algeria, Brazil, Chile, Morocco, Mexico, South Africa and Tunisia.

Brazil has the potential to become the largest producer and exporter of green hydrogen on the planet. The country can already produce the cheapest H2V in the world, according to data from BloombergNEF49 , because 70 per cent of the cost of producing green hydrogen comes from the cost of producing electricity from renewable sources.

On 10 September, Canal Energia published an article[50] on the **17 public policy proposals for the development and improvement of the national renewable hydrogen (H2R) market signed by the Brazilian Wind Energy and New Technologies Association (ABEEólica) and the Brazilian Photovoltaic Solar Energy Association (ABSOLAR), the Brazilian Biogas Association (Abiogás) and the German-Brazilian Chamber of Commerce and Industry of Rio de Janeiro (AHK Rio),** which were delivered by members of the Brazilian Renewable Hydrogen Pact to the representative of the Ministry of Development, Industry, Trade and Services (MDIC).

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48 https://br.boell.org/sites/default/files/2023-06/hidrogenio_verde_comercio_e_producao_pt_final.pdf

49 https://www.bloomberg.com.br/blog/valor-economico-bloombergnef-ve-lideranca-do-brasil-na-transicao-energetica/

50 https://www.canalenergia.com.br/noticias/53257027/associacoes-lista

The inclusion of H2R in the National Energy Policy, as well as conditions that enable financing, a reduction in the tax burden and credits, were among the structuring initiatives to promote the production and use of green hydrogen proposed by the group during Intersolar South America 2023.

According to the group's representatives, the search for solutions goes beyond the creation of public policies to reduce the cost of producing renewable energy compared to fossil fuels.

For them, it is also necessary to create programmes that create demand for green hydrogen on the domestic market, as has been done at other times with ethanol, biodiesel and renewable electricity sources. The proposals listed by the group were:

- According to the authors of the proposals, the legal definition of renewable hydrogen would be hydrogen produced from solar, wind, biomass, biogas, ethanol, geothermal, tidal and/or hydraulic sources, whether *onshore* or *offshore*, without directly emitting non-biogenic carbon dioxide into the atmosphere in its production cycle;
- Introduction of H2V in the National Energy Policy;
- Establishment of the ANP as a regulatory and supervisory agency (in line with the competences of Aneel, ANA, ANTAQ, environmental bodies and other entities);
- Equating hydrogen with biodiesel in terms of CBIOS emissions and inclusion in RENOVABIO to decarbonise the fuel sector;
- Amendment to the EPZ (Export Processing Zones) Law by means of incentives that make their creation and operation feasible. Creation of EPZs as hubs for the development of hydrogen projects in Brazil, with a view to the foreign and domestic markets;
- Reduction in the tax burden (PIS/COFINS, ICMS, IPI, II, IRPJ and CSLL) and tax credits for the renewable hydrogen production chain;
- Establishment of a national carbon market by law, with the aim of boosting green technologies in the country;
- REIDI and incentivised debentures for renewable hydrogen and its derived products as infrastructure projects;
- Exemption from sectoral charges such as CDE, PROINFA, CCC/CCEE and others, which fall on the share of consumption of renewable hydrogen projects. Compliance with REINTEGRA and extension of SUDENE (which will bring benefits of a 75 per cent reduction in income tax).
- Authorisation for renewable hydrogen to be included in the Presumed Profit Tax Regime for a period of 15 years, regardless of the billing limit, and with favourable IRPJ and CSLL presumption rates;
- Professional qualification for the development of H2V-related activities and the training of new professionals at both technical and higher education levels;
- Waiving additional environmental licensing requirements (such as the declaration of prior interference and decommissioning) and authorisations (with the ANP) for H2V production when there are parallels with other fossil hydrogen projects;

- Use of gas pipelines for the transport of renewable hydrogen, observing technical and safety issues;
- Increased access limit to the Climate Fund for renewable hydrogen projects (currently R$80MM/year);
- Reduction of the BNDES rate for renewable hydrogen and ammonia projects from 1.5 per cent p.a. to 1.1 per cent p.a. (like type A photovoltaic systems and solid waste energy);
- Development of a funding programme via FINEP to encourage projects focused on renewable hydrogen and ammonia (such as the programmes drawn up for 2G ethanol);
- Enabling low-cost financing for the purchase of machinery, inputs and the expansion of manufacturing capacity for equipment used in the production of renewable hydrogen.

These structural changes could enable Brazil to make an effective energy transition both domestically and globally. There will be interest in Brazilian hydrogen on the part of the European, Asian and North American markets, which will be obliged to purchase H2V at a competitive price if they are to achieve their local decarbonisation and global warming targets.

1 THE NATIONAL HYDROGEN PLAN (PNH2)

- (https://www.gov.br/mme/pt-br/programa-nacional-do-hidrogenio-1)

According to figures published by the Federal Senate's Environment Committee, the Green Hydrogen market is expected to reach US$2.5 trillion and represent around 20 per cent of the world's energy demand by 2030.

These figures are part of the justification for one of the bills currently before Congress that seek to regulate or define specific aspects of the exploitation of Green Hydrogen (H2V). The same document points out that this sector will receive approximately US$ 500 billion for the utilisation of H2V by the same date in Brazil.

This is a significant step forward when you consider that the current estimate for investments in Green Hydrogen in the country is around US$ 22 billion.

The Boston Consulting Group (BCG) has published a study in which it reports that between 2025 and 2050, between 6 and 12 trillion dollars will be invested in the green hydrogen sector, reaching the potential of 350 million tonnes per year by 2050, which represents a fourfold increase in consumption of this energy carrier.

These forecasts show that green hydrogen, for a number of reasons, is leading the race to adopt new sustainable energy matrices.

Faced with these new economic horizons - always with decarbonisation as a principle - in 2021 the Brazilian government, through the Ministry of Mines and Energy (MME), formulated the guidelines for the National Hydrogen Programme (PNH2).

At the end of 2022, the agency proposed a public consultation (Public Consultation 147/2022) to collect general demands and ideas from the sectors involved and from the population as a whole, with the aim of these manifestations contributing to the effectiveness of the federal government's actions.

The National Hydrogen Programme (PNH2), instituted by Resolution No. 6 of 23 June 2022 by the MME, established public policies to stimulate technological development and the creation of a hydrogen market in the country.

The resolution also defined the governance structure, with the coordination and supervision of the planning and implementation of actions by a Management Committee made up of various bodies and entities of the Federal Public Administration.

As the PNH2 presentation text makes clear, the Brazilian government identified the need to organise strategic actions aimed at developing the hydrogen economy in Brazil.

The National Energy Policy Council (CNPE) then created the **National Hydrogen Programme Management Council (Coges-PNH2) to formulate the three-year hydrogen plan.**

The regulatory legislation on the production, distribution and marketing of green hydrogen presented by members of parliament in the Senate and the Federal Chamber depends on the definitions and guidelines produced by the implementation of PNH2, a programme led by the Ministry of Mines and Energy, but also involving other ministries, bodies and agencies.

To this end, the themes were divided into **thematic chambers** under the coordination of certain ministries. The Three-Year Plan will be developed on the basis of the studies promoted by **5 Thematic Chambers**:

a) **Thematic Chamber for Strengthening Scientific and Technological Foundations**

Under the coordination of the MCTI - Ministry of Science, Technology and Innovation and with the aim of supporting research, technological development, innovation and entrepreneurship in the production, storage, transport, safety, use and applications of Hydrogen. The Chamber is guided by 3 goals:
Consolidate the **Brazilian Hydrogen Initiative** (IBH2) as the scientific and technological development module of the National Hydrogen Programme (PNH2) by 2025;
Structuring the **Brazilian Hydrogen Laboratory System (SisH2-MCTI)** by 2023; and
Consolidate a **National Discussion Forum on Hydrogen ST&I** by 2025.
b) **Thematic Chamber for Human Resources Training**
Coordinated by the Ministry of Education (MEC), its aim is to develop national human resources with the skills to plan, licence, implement and operate projects related to the production, transport, storage and use of hydrogen.
This thematic chamber has the following goals:
Technical and professional training;
Human resources and disciplines at undergraduate and postgraduate level;
Patents, books, technical and scientific publications and research groups;
Training within the public sector; and
Exchange between the public and private sectors and academia.
c) **Energy Planning**
Coordinated by the Ministry of Mines and Energy (MME). Its objective is to promote studies related to the hydrogen energy chain, which will improve the representation and modelling of this energy chain in the official Brazilian energy planning process and its goals include:
Carrying out studies on the supply, logistics (transport and storage), conversion and consumption of hydrogen and its derivatives, taking into account the socio-economic, energy and environmental dimensions.
d) **Legal and Regulatory Framework**

Coordinated by the Ministry of Mines and Energy (MME), its aim is to improve the institutional, legal and infra-legal frameworks for the development of low-carbon hydrogen in Brazil:
Remove barriers in the legal and regulatory framework that make it difficult to attract investment in the sector;
Alignment of national and international regulations;
Interrelationships between sectors;
Standards related to safety and new uses and technologies.
e) Market Opening and Growth and Competitiveness
Under the coordination of the Ministry of Economy, it aims to develop and consolidate the hydrogen market in Brazil and the country's international insertion on an economically competitive basis. Its goals include:
Mapping the hydrogen value chain in Brazil, identifying rapidly disseminating demands for the application of hydrogen and considering aspects related to financing, carbon pricing and infrastructure;

Support the construction of a Brazilian hydrogen strategy as an energy alternative in order to increase the country's competitiveness and fulfil its commitments under the Paris Agreement..

The purpose of each of these thematic chambers is to draw up a three-year work plan, to be approved by the management committee (Coges-PNH2) at an ordinary meeting.

The PNH2 established three dates as milestones for the implementation of the National Hydrogen Policy. The National Secretariat for Energy Transition and Planning of the Ministry of Mines and Energy has clarified that the hydrogen strategy for the country will, in principle, observe the following 03 milestones.

The first, in 2025, proposes the creation of pilot hydrogen plants that operate with low carbon emissions in all regions of the country.
Secondly, in 2030, the aim is to make Brazil the most competitive producer of green hydrogen in the world.
The third will take place in 2035, with the consolidation of low-carbon hydrogen "hubs" in Brazil.

According to the National Energy Transition Secretariat, Brazil has the technical potential to generate 1.8 gigatonnes of hydrogen per year. Recent indicators show that Brazil is the country with the lowest green hydrogen production costs in the world.

The establishment of the regulatory framework will make it possible for annual investments in hydrogen in Brazil to be 7 times greater than they are today, as well as increasing access to competitive financing from development banks to make projects on a larger scale viable.

Prospects and Current Legislation Related to Hydrogen

Any new technology requires a regulatory framework to realise its use throughout the value chain. Interest in green hydrogen requires adaptation of industrial parks and the implementation of guidelines involving organised and coordinated actions. Observing the policies adopted by countries that are developing the hydrogen economy shows how essential it is to establish a global vision, materialised in a national strategy in line with the interests of each nation.
One of these strategies can be seen in the drive to develop this economy through targets for reducing greenhouse gas (GHG) emissions; diversifying the energy matrix; balancing the energy matrix; and economic growth.

In Latin America, according to a study by IPEA called "Panorama do Hidrogênio no Brasil" (Hydrogen Panorama in Brazil)[51] , the Energy and Sustainability programme of the Institute of the Americas assessed the potential for H2 in Latin America, taking into account a number of criteria, such as the existence of a regulatory framework, the domestic market and demand, among others, obtaining favourable indicators for Brazil. According to the study, there is an expectation of a significant increase in hydrogen demand by 2030, due to economic growth, with Trinidad and Tobago, Brazil, Chile and Mexico standing out in the Americas.

51 https://repositorio.ipea.gov.br/bitstream/11058/11291/1/td_2787_web.pdf

DRAFT LAWS ON HYDROGEN - FEDERAL SENATE AND CHAMBER OF DEPUTIES

PROPOSALS IN PROGRESS

A number of proposals to regulate hydrogen and establish a regulatory framework are currently before Congress.
The following bills are being processed in the Federal Senate:

Senate Special Committee Bill on Green Hydrogen - Provides for the low-carbon hydrogen industry and its typifications, provides for the respective structure and sources of funds, and amends Law No. 9.478, of 6 August 1997, Law No. 9.427, of 26 December 1996, Law No. 10.438, of 26 April 2002, Law No. 11.488, of 15 June 2007, Law No. 11.508, of 20 July 2007 and makes other provisions.

Bill No. 1.878/2022 - Creates a policy regulating the production and use of green hydrogen for energy purposes.

Bill No. 725/2022 - Regulates the insertion of hydrogen as an energy source in Brazil, and establishes parameters to incentivise the use of sustainable hydrogen.

Bill No. 3.173/2023 - Creates Prohidroverde - the National Green Hydrogen Programme, aimed at promoting the production, distribution and use of hydrogen generated from renewable energy sources

The Chamber of Deputies is processing the following bills:

Bill No. 2.308/2023 - Provides for the legal definition of hydrogen fuel and green hydrogen.

Bill No. 3.452/2023 - Provides for the concept of and incentives for the energetic use of hydrogen in Brazil (pending as an appendix to Bill No. 2.308/2023).

On 12 April 2023, the Federal Senate set up the Special Committee to Debate Public Policies on Green Hydrogen (CEHV). The purpose of this temporary (two-year) commission is to debate public policies on H2V that encourage the use of this clean energy generation technology.

During the committee hearing on 24 May 2023, state representatives raised topics of interest such as: the need for federal regulation of *offshore* wind; the need for greater speed in defining objective targets in the National H2 Programme; the need to reduce the CNPE's slowness in defining the PNH2; the urgency of defining a national H2V strategic plan with objective targets, deadlines and amounts to be invested.

On 7 June 2023, the Senate Committee heard from representatives of banking institutions that finance sustainable energy generation projects, such as the IDB, Banco do Nordeste do Brasil, Caixa Econômica Federal, Banco do Brasil and BNDES. The BNDES representative signalled that Brazil must be prepared to meet external demand, but at the same time identify the production chain within the country to make use of it.

The Bill of the SPECIAL COMMISSION TO DEBATE PUBLIC POLICIES ON GREEN HYDROGEN OF THE FEDERAL SENATE is the most complete Bill presented on hydrogen in the National Congress, encompassing the main points of the other bills and bringing new concepts to the regulatory framework. For this reason, it is the first on the list of Bills analysed in this study.

In parallel with the move by the President of the Commission, Senator Cid Gomes (PDT/CE), to speed up the issue, the National Secretary for Energy Transition and Planning of the Ministry of Mines and Energy, Thiago Barral, was in the Chamber of Deputies last week to discuss the draft bill and the National Hydrogen Plan (PNH2) and defended the need for a regulatory framework.

The PL was to be officially presented on 4 October 2023, but this date was postponed to 18 October 2023.

The states are waiting for the Federal Government to define the regulatory framework as a matter of urgency, because the state entities want to create their own public policies to encourage hydrogen, and they depend on the terms of a federal regulation. Some have already developed their own hydrogen regulations, according to their characteristics and potential, such as the states of Ceará, Pernambuco, Paraná, Goiás, Rio Grande do Norte and others.

BILL FROM THE FEDERAL SENATE'S SPECIAL COMMITTEE ON GREEN HYDROGEN

SPECIAL COMMITTEE BILL ON GREEN HYDROGEN (FEDERAL SENATE)
(https://legis.senado.leg.br/comissoes/comissao?codcol=2589)

The Senate Special Committee Bill on Green Hydrogen provides for the low-carbon hydrogen industry and its typifications, provides for the respective structure and sources of funds, and amends Law No. 9.478, of 6 August 1997, Law No. 9.427, of 26 December 1996, Law No. 10.438, of 26 April 2002, Law No. 11.488, of 15 June 2007, Law No. 11.508, of 20 July 2007 and makes other provisions.

It is definitely the most comprehensive and technically well-prepared of all the bills presented so far. Developed by the commission specially created to work on the legal framework for hydrogen in Brazil, the bill contains principles, technical definitions, regulatory aspects, incentives and other issues that directly impact the green hydrogen production chain, divided into 37 articles. Let's analyse the main topics:

1 Justification for the Bill

In the bill's justification, the authors clarify that the bill sought to establish a proposal that dealt with low-carbon hydrogen, as well as two sub-classifications applied to it: renewable hydrogen and green hydrogen. They state that, "the purpose of considering these sub-classifications was to allow specific regulatory treatments for these last two groups, considering some peculiarities that are typical (...)." To illustrate the point, the bill's justification includes the image below as an example.

2 The principles and objectives of the low-carbon hydrogen incentive policy

The **principles of** the Low Carbon Hydrogen Incentive Policy are very similar to the structuring axes of the PNH2 Programme. They are: i) strengthening scientific and technological bases; ii) training human resources; iii) energy planning; iv) legal and regulatory frameworks; and v) opening up and growing the market and competitiveness; and VI - international co-operation.

More broadly, the **objectives of the Low Carbon Hydrogen Incentive Policy** are set out in Article 3. There are 16 objectives, ranging from preserving the national interest to fostering the energy transition; encouraging production routes by valuing the multiple national economic vocations; expanding the labour market for hydrogen production chains; protecting consumer interests in terms of price, quality and a stable and permanent supply of low-carbon hydrogen and its derivatives; attracting and encouraging national and foreign investment in the production of low-carbon hydrogen and its derivatives; attracting investment in transport and storage infrastructure; fostering research and technological development, among others.

A series of new concepts and technical definitions are part of the hydrogen market, definitions that do not exist in the legal system and that for the first time appear in a legal document. **Article 4 of the Bill is dedicated to bringing new technical definitions to the market**. There are 10 new concepts inserted into the Brazilian legal system through the hydrogen regulatory framework.

Low-carbon hydrogen: hydrogen fuel or industrial input, collected or obtained from different sources in the production process and which has greenhouse gas (GHG) emissions of less than or equal to four kilograms of carbon dioxide equivalent per kilogram of hydrogen produced (4 $kgCO_2eq/kgH_2$);

Renewable hydrogen: hydrogen fuel or industrial input, collected or obtained from renewable sources, including solar, wind, hydraulic, biomass, biogas, landfill gas, geothermal, tidal and oceanic and ambient;

Green hydrogen: renewable, low-carbon hydrogen produced from the electrolysis of water using solar and wind sources, respecting the criterion of additionality and observing the criteria of temporality or the requirement of a minimum renewable generation of 90 per cent on an annual basis per subsystem;

Hydrogen derivatives: products of industrial origin that have hydrogen, produced in the forms provided for in this article, as an input in the production process;

Hydrogen certificate: certification of low-carbon hydrogen or its types, issued by an agent authorised by a competent authority, attesting to the characteristics of the production process, which must include at least the contractual characteristics of the inputs used, the location of production and the quantity of carbon dioxide equivalent emitted, in addition to the provisions of regulations;

Additionality: an assessment criterion for low-carbon hydrogen that requires all inputs used in its production to come from dedicated sources or sources added to the system as a result of its implementation;

Temporality: a criterion for evaluating low-carbon hydrogen used for projects that do not meet the additionality requirement, which considers the time of its production for the purposes of evaluating the displacement of its inputs by others with high carbon emissions;

Risk Analysis Study (RAS): an integral part of the environmental study that includes assessing the vulnerability of the project and the region in which it is located, including techniques for identifying hazards, estimating the frequency of abnormal occurrences and risk management.

Risk Management Plan (RMP): document that describes how the risk management of the project will be carried out, monitored and controlled; and

Emergency Action Plan (PAE): an integral document of the project's risk management plan that establishes the actions to be carried out by the entrepreneur in the event of an emergency situation and identifies the agents to be notified.

These are important concepts that deserve to be highlighted and commented on:

In addition to low-carbon hydrogen, the distinction between renewable hydrogen and green hydrogen is noteworthy. **Renewable hydrogen** is that obtained from renewable sources, including biomass and biogas. To be considered **green hydrogen, it** must be obtained exclusively through the electrolysis of water using solar and wind sources, and must meet additionality and temporality criteria (new concepts), or prove the use of 90 per cent renewable generation to obtain it, calculated on an annual basis.

In Mele's project we will have a **hydrogen-derived** product, either e-methanol or synrude.

To obtain the **hydrogen certificate,** the company must demonstrate the characteristics of the production process, the contractual characteristics of the inputs used, the location of production and the amount of

carbon dioxide equivalent emitted, in addition to the provisions of the regulations.

In order for the Mele Biogas GmbH/GIZ project to comply with the term "contractual characteristics of the inputs used", it is important that the contract for the supply of the inputs used specifies the physical and chemical characteristics of the biomass used, its origin, certificates from the respective health surveillance bodies, environmental licences and others that prove the origin of the input. Note that other requirements and greater specificity will be introduced when the text mentions "in addition to the provisions of regulations", which will come later through ANP rules.

The concept of additionality, brought in as an assessment criterion, states that all inputs used in production come from dedicated sources or are added to the system as a result of its implementation. What is additionality? Additionality is proven when, as a result of a project, other sources of renewable energy generation are created, other wind, photovoltaic or biogas plants, for example, meaning an additional increase in the grid with new clean source plants. One of the ways of proving additionality are I-RECs, renewable energy certificates.

Temporality: low-carbon hydrogen assessment criterion used for projects that do not meet the additionality requirement. The Mele Biogas GmbH/GIZ project will be able to meet the additionality criterion by building new plants. If it does not, the temporality criterion will be applied in order to assess the sources used from the moment the plant is commissioned and produces (commissioning).

Risk Analysis Study (RAS): an integral part of the environmental study that includes an assessment of the vulnerability of the project and the region in which it is located, including techniques for identifying hazards, estimating the frequency of abnormal occurrences and risk management. Also included in the EAR are the Risk Management Plan (RMP) and the Emergency Action Plan (EAP), documents that must demonstrate the project's critical risk points, their management and the strategy in the event of emergencies. In the case of Mele's project, I believe that one of the main points that should be studied is the logistics of pig farming inputs, their form and treatment, the modes used, whether or not pipelines are used, handling and disposal. The issue of the project's biogas raw material involves environmental and health surveillance aspects that should be highlighted in the EAR, PGR and PAE.

The Bill includes a chapter on Governance and its articles 5 and 6 establish the Low Carbon Hydrogen Steering Committee - CGHBC, responsible for managing the Low Carbon Hydrogen Incentive Policy in Brazil. The CGHBC is responsible for:

- establish the guidelines for implementing the Low Carbon Hydrogen Incentive Policy;
- to assess appeals relating to requests for authorisation of projects for the production of low-carbon hydrogen and its derivatives, requests for extensions and the tax regime applicable to the sector;
- issue standards and policies for the production and use of low-carbon hydrogen and its derivatives;
- hear appeals against the cancellation or withdrawal of authorisations;
- coordinating the actions of the Low Carbon Hydrogen Development Programme - PHBC; and
- establish guidelines for certifying the origin of low-carbon hydrogen and its derivatives.
- The CGHBC would be made up of representatives from 11 ministries plus the National Electric Energy Agency (ANEEL), the National Petroleum, Natural Gas and Biofuels Agency (ANP) and the Energy Research Company (EPE).
- The CGHBC may invite experts or representatives from other bodies, organisations, associations and public or private agents to take part in meetings and provide advice on specific issues.

- When dealing with the production of low-carbon hydrogen, Article 9 of the bill defines the regulatory bodies and the characteristics of the companies that will be able to exploit production.

- Production activities will be carried out by a company or consortium of companies incorporated under Brazilian law, with headquarters and management in the country, authorised by the competent regulatory body.

- Authorisation for the production of low-carbon hydrogen will come from the National Agency for Petroleum, Natural Gas and Biofuels (ANP).

- The National Electric Energy Agency (Aneel) will be responsible for authorising the production of hydrogen from the electrolysis of water.

Attention should be paid to the different ways in which authorisations are issued. If the project involves hydrogen from the electrolysis of water, the company must also obtain authorisation from Aneel.

When dealing with the rules that will be drawn up by the regulatory agent, article 10 provides that the so-called regulatory sandbox arrangement, referred to in item II of article 2 of Complementary Law no. 182, of 1 June 2021, may be used.

Subsection II of art. 2 of Complementary Law no. 182/2021 defines a regulatory sandbox as an "*experimental regulatory environment and a set of special simplified conditions, so that participating legal entities can receive temporary authorisation from the bodies or entities with sectoral regulatory powers to develop innovative business models and test experimental techniques and technologies, by complying with criteria and limits previously established by the regulatory body or entity and by means of a facilitated procedure*".

As you can see from the concept of Law 182/2021, the regulatory sandbox is an experimental regulatory environment where participants can receive temporary authorisation to develop innovative business models, techniques and technologies, subject to criteria and through a facilitated procedure. The Mele Biogás project is highly innovative and we can think of this type of facilitated framework for hydrogen production ventures.

Article 11, on the other hand, validates authorisations in force at the time of the law's publication, subject to an analysis of compliance by the competent regulatory body.

The ANP as a regulatory body is once again highlighted in article 12, as the agency that issues authorisations for activities related to the loading, processing, treatment, import, export, storage, stocking, packaging, transport, transfer, distribution, resale and marketing of hydrogen.

And the sole paragraph states that agents who obtain authorisation for the production of low-carbon hydrogen will have priority in the processing of applications for authorisation under the heading of this article.

Note that the PL's sole paragraph states that companies that obtain authorisation to produce low-carbon hydrogen will have priority in the processing of other authorisation requests, which allows us to conclude that each activity mentioned will have a specific authorisation.

Therefore, loading, processing, treating, importing, exporting, storing, packaging, transporting, transferring, distributing, reselling and marketing hydrogen will require a specific authorisation.

Chapter IV of the Bill deals with incentives for the Low Carbon Hydrogen Policy and includes tax and regulatory incentives.

In the tax incentives of articles 13 and 14, the bill mentions the incentives for the use of EPZs - Export Processing Zones, regulated by Law 11.508/2007, which allow the purchase and import of machinery, equipment and raw materials, as well as the contracting of services, with the suspension and exemption of the following taxes:

I - Import Tax;
II - IPI;
III - Cofins;
IV - Cofins-Import;
V - Contribution to PIS/Pasep;
VI - PIS/Pasep-Import Contribution; and
VII - AFRMM.

The project that opts for the EPZ incentives cannot benefit from other tax regimes for the development of the low-carbon hydrogen industry established in a specific law.

Electricity, water, steam, natural gas and others provided for in the regulations will be classified as raw materials for the purposes of the Export Processing Zones (EPZ) incentives.

The term of the benefits granted to companies established in EPZs is 20 years, renewable after this period. Export Processing Zones can be created by federal decree, at the request of the municipality, subject to the criteria and procedures set out in Law 11.508/2007 and regulations.

When dealing with regulatory incentives, the Senate Commission Bill included in its article 15, the mandatory addition of low-carbon hydrogen to transport pipelines, in minimum volumetric percentages of:

- 5% (five per cent), from January 2028;
- 10% (ten per cent), from January 2033;
- 15% (fifteen per cent), from January 2040.

This hydrogen addition must contain a mandatory proportion of renewable hydrogen of at least 20 per cent by 2028 and at least 60 per cent by 2033 and 2040. The percentages could be staggered according to the safety capacity of transport and supply.

In one of its paragraphs (4th), the bill states that the percentage of low-carbon hydrogen added cannot exceed 20 per cent per stretch of pipeline.

The ANP will issue regulations governing the transport of low-carbon hydrogen and renewable hydrogen via gas pipelines, delimiting volumes, tariff calculations, stretches of pipeline and other aspects. At state level, for projects that use hydrogen as a final product, it would be important to map the gas pipeline network of COMPAGÁS - Companhia Paranaense de Gás, which has the concession for the network of pipelines in the state.

The use of the transmission network by the power plant and by the plants that supply the renewable energy that is an input for production generates the obligation to pay charges relating to TUST - Tariff for the Use of the Electricity Transmission System (article 16).

However, the bill equates hydrogen producers and energy consumers with self-producers, under the terms of Article 3-A of Law No. 10,848/2004, provided that:

- produce green hydrogen, as defined by law;
- the consumption and generation of electricity are located in the same concession area;
- participates in a special purpose company set up to exploit, by means of authorisation or concession, the production of electricity; and
- the operation of the electricity-producing SPE begins the commercial operation of energy consumption and generation as of the date of publication of this Law, meeting the additionality criterion under the terms of the Law.

The benefit for self-producers of energy, under the terms of Article 3-A of Law 10.848/2004, is the contracting of reserve capacity or reserve energy, with the possibility of the administrative and financial costs and tax charges being apportioned among all the end users of electricity in the SIN, but self-producers only for the portion of the electricity resulting from their interconnection to the SIN - National Interconnected System. The bill stipulates this benefit for a period of 10 years.

This benefit can only be claimed if the SPE produces green hydrogen. The PL does not specify whether the green hydrogen should be the end product or an intermediate product used in the production process of one of its derivatives.

In order for Mele Biogás GmbH to claim the benefit, the criteria must be met cumulatively. The additionality criterion, together with consumption and generation of electricity in the same concession area, means that the power plants supplying energy to the project must be new and built in COPEL's area.

In corporate terms, SPE Mele Biogás GmbH should have a shareholding in the SPES of the new plants set up to produce electricity.

Article 17 stipulates that the costs associated with the regulatory incentives provided for in articles 16 and 35 of this law will be remunerated by reimbursement to the Energy Development Account (CDE) referred to in article 13 of Law 10.438 of 26 April 2002, with funds to be obtained from the Low Carbon Hydrogen Development Programme, referred to in articles 18 et seq. of the bill.

The costs of the regulatory incentives for becoming a self-producer of energy will be remunerated by reimbursement to the Energy Development Account (CDE), with funds from the Low Carbon Hydrogen Development Programme, referred to in articles 18 and following.

The benefit mentioned in article 35 refers to REIDI - the Special Incentive Scheme for the Development of Infrastructure, where the beneficiary that has an approved project for the implementation of infrastructure works in the transport, ports, energy, basic sanitation and irrigation sectors, has the suspension of PIS and COFINS taxes on the import and purchase of machinery and equipment.

Articles 18 to 21 of the bill provide for the creation of the Low Carbon Hydrogen Development Programme - PHBC, of an accounting and financial nature, linked to the Presidency of the Republic, with the aim of providing a source of funds for the energy transition by equalising production costs and promoting the development of low carbon hydrogen, renewable hydrogen and green hydrogen.

The **PHBC may grant economic subsidies** to companies authorised to carry out hydrogen production activities, for the sale of inputs used in the production of low-carbon hydrogen on national territory, for consumption on the domestic market and for export purposes, **provided they are certified in** accordance with the law.

The economic subsidy of the PHBC will be limited to a period of ten years from the date of publication of the law.

An important incentive for **hydrogen and derivatives projects** brought in by the Bill in **Article 22** is the possibility of **issuing incentivised debentures, as** referred to in Article 2 of Law 12.431/2011.

Electricity generation projects **and associated connection networks** may also be part of the project's debenture issue.

Hydrogen production projects can seek funding via the capital markets by issuing incentivised debentures, which grant an income tax exemption for individuals and a 15% rate for companies.

Certification of hydrogen projects was also addressed in the bill, which in its **articles 23 to 25 provides that** the Federal Executive Branch may **create a certification system**, including origin and characteristics, for the types of hydrogen and its derivatives provided for in the law, meeting international standards for hydrogen mixtures with different amounts of carbon equivalent.

Regulatory bodies will have to create a **register to accredit certifying institutions** and certification data will be public, except in situations involving industrial secrecy and others provided for in regulations.

Water is an essential input for the production of hydrogen through electrolysis. The bill created the chapter **on the use of water for hydrogen production, in** which article 26 provides for priority for analysing and issuing permits for the use of water resources for the production of low-carbon hydrogen, and the permit may be suspended in cases of declared water scarcity in the country.

The bill also encourages the use of water from desalination processes, as well as rainwater and the non-potable reuse of water from buildings, and prohibits the issuing of grants and the use of water resources for projects in locations with conflicting water use, with the Federal Executive Branch establishing the locations with conflicting water use.

The Senate Committee Bill also opened a chapter to support the development of low-carbon hydrogen projects in line with the **carbon market** and the mechanisms of the **Paris Agreement**.

Among the measures are: i) enabling participation in the international transfer mechanisms provided for in Article 6 of the Paris Agreement; ii) encouraging the adoption of a methodology for certifying carbon assets generated within the scope of hydrogen production; iii) encouraging the participation of companies in the low-carbon hydrogen industry and its derivatives in the generation and trading of assets within the scope of the voluntary carbon markets and the national and international greenhouse gas (GHG) emissions trading systems.

The Federal Government's Low Carbon Hydrogen Development Programme (PHBC) will be able to subsidise the process of certifying the carbon assets of companies in the hydrogen industry for a period of 10 years from the publication of the Law, provided that the additionality requirement is met. The international transfer

mechanisms set out in Article 6 of the Paris Agreement, especially sub-items 6.4 and 6.6, refer to the rules for carbon projects that will have their credits acquired by developed countries under the *cap and trade* modality.

On 04/10/2023, the Federal Senate approved Bill 412/2022, which regulates the carbon market in Brazil, creating the Brazilian Emissions Trading System (SBCE) for companies that emit more than 10,000 tonnes of GHG per year.

At the end, the Bill brings legal changes, of which we highlight the following:

Modification of Law No. 9.478/97, which creates the National Energy Policy and the ANP - National Agency for Petroleum, Natural Gas and Biofuels, the regulatory body for the national low-carbon hydrogen policy, including allowing the declaration of public utility, for the purposes of expropriation and the establishment of administrative servitude, of the areas necessary for the construction of essential infrastructure for the production of hydrogen; (amendment of article 8 of Law No. 9.478/97).

Ensuring resources from the Energy Development Account (CDE) and the Low Carbon Hydrogen Development Programme (PHBC) for the production and use of green hydrogen with a view to the energy transition, with the creation of a specific sectoral charge or an increase in CDE costs being prohibited (amendment to Law 10.438/2022).

Amends Law No. 9.427/96, which creates the National Electric Energy Agency (ANEEL), to authorise green hydrogen production activities to be carried out by any company or consortium of companies incorporated under Brazilian law, with headquarters and administration in the country.

Amends Law 11.488/2007 to equate hydrogen producers with self-producers of electricity, for the purposes of qualifying for the Special Incentive Regime for the Development of Infrastructure - REIDI, subject to the criteria stipulated in the Law.

The Export Processing Zones - EPZs, created by Law 11.508/2007, can have discontinuous areas covered by the EPZ area, within the limit of 30km of the area destined for projects subject to customs clearance for export. The bill extends this limitation to 50 kilometres from the project area, provided that it is dedicated exclusively to the production of low-carbon hydrogen.

BILL NO. 1.878/2022 - (FEDERAL SENATE)

(*https://www25.senado.leg.br/web/atividade/materias/-/materia/153923*)

Bill 1.878/2022, presented by the Senate Environment Committee, creates a policy to regulate the production and use of green hydrogen for energy purposes.
Among the technical definitions contained in the Bill, we highlight the following legal concepts in Article 1:

Renewable Sources;
Green Hydrogen, which emphasises hydrogen obtained through the electrolysis of water, with renewable sources and without the emission of carbon dioxide in its production;

Electrolysis of water: the process of decomposing water into oxygen and hydrogen by passing an electric current through the water;
Declaration of Prior Interference (DIP): a declaration issued in order to identify the existence of interference by Green Hydrogen production projects with other installations or activities;
Official Development Finance Agency (AFOF): a federal public financial organisation whose role is to provide financing for various undertakings.

The bill regulates green hydrogen and links its exploration and production to the national interest, public utility, energy security, environmental protection and defence.

In its articles 4 and 5, the bill adds green hydrogen to the items that must be regulated and supervised by the National Petroleum Agency (ANP), amending Law 9.478/98 and establishing the ANP as the regulatory agency.

Bill No. 1,878/2022 establishes the ANP as the entity responsible for regulating the green hydrogen industry. It will be responsible for implementing the national policy for oil, natural gas, biofuels and green hydrogen throughout the country and protecting consumer interests in terms of price, quality and supply of products, as well as overseeing its industrial activities, organising and maintaining good conservation and rational use practices.

It will also be in charge of regulating, authorising and supervising all activities in the green hydrogen chain, including imports, exports, storage, stockpiling, checking standards of use and injection at delivery and exit points, as well as issuing licences for production.

Amongst its attributes related to green hydrogen would also be:

the implementation of its national policy;

supervise directly, or through agreements with state and Federal District bodies, the activities of the oil, natural gas, biofuels and green hydrogen industry, as well as apply the administrative and pecuniary sanctions provided for by law, regulation or contract;

the application of administrative and pecuniary sanctions provided for by law, regulation or contract;

the organisation and maintenance of the collection of information and technical data relating to green hydrogen, as well as the maintenance of good practices aimed at preserving the environment;

specify the quality of oil derivatives, natural gas and its derivatives, biofuels and green hydrogen;

regulate, authorise and inspect the activities of the green hydrogen chain, including production, import, export, storage, stockpiling, standards for use and injection at delivery points or points of exit;

Basically, the ANP will be responsible for everything related to green hydrogen - from its specific regulation, authorisations, inspection and the application of administrative and financial sanctions.

In Article 6 - Hydrogen Production, the Bill provides guidelines for companies wishing to explore this activity in Brazil.

It is important to emphasise that the company must be incorporated in Brazil, with its head office and administration in Brazilian territory.

The law states that "*any* ***company or consortium*** *of companies incorporated under Brazilian law with headquarters and administration in the country may obtain a licence from the ANP to carry out economic activities for the production of Green Hydrogen, and that the licence referred to in the caput is intended to allow the exploitation of economic activities under a regime of free enterprise and broad competition.*"

The possibility of a consortium of companies is not an illegal innovation, since companies can join together to carry out economic activities as a constitutional guarantee of the principle of free enterprise. The setting up of consortia between companies is also provided for in the Corporations Law (Law No. 6,404/76), as it is common market practice for companies to join technical, scientific and financial endeavours that complement each other in order to legally exploit a certain economic activity. The Special Purpose Company (SPE) has also become a widely used vehicle for companies wishing to join forces for a particular venture or economic activity.

In order to obtain the licence to be issued by the ANP, the company must prove, where applicable, the conditions laid down in a specific law, in addition to the following, in accordance with regulations:

> I - be constituted under Brazilian law, with headquarters and administration in the country;
>
> II - show that it is in good standing with the federal, state and municipal treasuries, as well as demonstrating that it is in good standing with the ANP;
>
> III - submit a basic project for the installation, in accordance with the norms and technical standards applicable to the activity;
>
> IV - present an environmental licence, or another document that replaces it, issued by the competent environmental body;
>
> V - submit a security control project for the installations approved by the competent body;
>
> VI - hold paid-up share capital or present other sufficient sources of funding for the venture.

In this regard, it is important to highlight the requirement for paid-in capital and proof of the financial capacity of the company responsible for the project, which, at the time of the licence application, is already in place, must prove that the investment capital is their own, or in the case of financing from national and international institutions, provide documentary evidence of the credit line and guarantees available.

The licence holder may lose the licence, which will be annulled if the act was issued illegally;

The licence shall be revoked if the beneficiary of the licence fails to comply with the conditions laid down in the granting act, without giving rise to any right of compensation for the offender; revoked, provided they are motivated.

The licence cannot be granted if the interested party or the group to which they belong has, in the five (5) years prior to the application, had a licence to carry out an activity regulated by the ANP withdrawn as a result of a penalty applied in an administrative process with a final decision.

The Bill binds the projects to the National Water Resources Policy (Federal Law 9.433/1997) and to the regulations of the National Water and Basic Sanitation Agency (ANA), when the projects make use of water resources to generate green hydrogen.

The green hydrogen production unit that commercialises electricity must comply with the rules and regulations established by the National Electric Energy Agency (ANEEL) and other competent bodies and entities.

In Article 7 - Special Procedures for Issuing a Licence for the Production of Green Hydrogen, the bill also states that the issuing of the licence is linked to the issuing of a Declaration of Prior Interference (DIP), to be issued by the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA). The concept of DIP is set out in Article 2.

Article 10 establishes that the definition of the area for the implementation of projects for the production of Green Hydrogen will establish the spaces in which the interested party will include facilities ancillary to the production and generation of electricity, including areas for the storage and transport of Green Hydrogen, and for the transmission of electricity.

Defining the Green Hydrogen transport area is something that would require defining and presenting the route for transporting the final product produced at the project stage, which I believe is difficult to define at this stage, since logistical and marketing issues can only be modified or defined over time according to demand. On the other hand, there is a need for a prior strategic definition, already at the project stage, of how the production will be marketed and sold, which could be proven through memoranda of understanding and specific contracts.

The Bill is concerned in more detail with the obligations linked to the use of water resources.

Article 11 of the bill lays down obligations for the holder of the licence to use water resources:

- adopt the necessary measures to ensure the economical use of water resources in the Green Hydrogen production process, the safety of people and installations, and the protection of the environment;

- immediately notify the ANP, ANEEL and ANA of any relevant facts that affect the institutional objectives of these authorities;

- be civilly liable for the acts of their agents and indemnify any and all damage arising from their activities, and must reimburse the Federal Government for any costs it may incur as a result of any claims arising from the acts of authorised agents.

A detailed plan for the use of water resources would already be required at the project stage in order to obtain a licence from the National Water and Sanitation Agency (ANA). The regulatory agency for water and water resources would then issue regulations governing the requirements for a licence.

The R&D incentives are in article 12, which deals with incentives for the "green hydrogen segment", and establishes that "within 10 years of the publication of this law, the Executive Branch will provide incentives for Research, Development and Innovation (RD&I), by offering lines of credit for RD&I by entities of the Administration characterised as AFOF".

The use of labour and its training are provided for in **article 13,** which states that "the licensing of Green Hydrogen projects, as well as their access to credit encouraged by the Federal Government, are conditional on the licensee's commitment to the **training and education of the workers** involved in the project".

And finally, in the **general provisions**, the bill specifies that all licensing acts for green hydrogen production projects must detail:

- project management and planning;
- how the removal of project-related infrastructure will be carried out;
- post-decommissioning processes, such as the destination of the removed elements, site recovery and monitoring;
- the project phases, and
- the respective decommissioning clauses.

BILL NO. 725/2022 - (FEDERAL SENATE)

(*https://www25.senado.leg.br/web/atividade/materias/-/materia/152413*)

The Federal Senate is currently working on another bill on the subject, authored by former senator and current president of Petrobras, Jean Paul Prates, which is Federal Bill No. 725/2022, which "regulates the insertion of hydrogen as an energy source in Brazil, and establishes parameters to incentivise the use of sustainable hydrogen."

Nicknamed the "Hydrogen Law", Prates' initiative amends the texts of Federal Laws No. 9.478/97 and No. 9.847/99, which regulate the fuel sector in Brazil.

Law 9.478/97 provides for national energy policy, activities relating to the oil monopoly, establishes the National Energy Policy Council and the National Petroleum Agency and makes other provisions. It is the legal framework for Brazilian energy policy.

Federal Bill No. 725/2022 **brings structural changes to include hydrogen in the national energy policy, but does not provide further details on regulatory aspects, leaving the regulation of the matter to the ANP.**

The Bill amends article 6 of Law 9.478/97, which establishes technical definitions for regulatory purposes. In this sense, it brings in the definitions of "hydrogen" and "sustainable hydrogen", which are:

> XXXII - **Hydrogen:** pure hydrogen that remains in a gaseous state under normal conditions of temperature and pressure, collected or obtained from various sources, through the use of specific technical processes or as a by-product of industrial processes.
> XXXIII - Sustainable hyd**rogen**: hydrogen produced from solar, wind, biomass, biogas and hydraulic sources."

"**Sustainable hydrogen**" would therefore be hydrogen produced from renewable energy sources (solar, wind, biomass, biogas and hydro). The concept of sustainable hydrogen is linked exclusively to the energy source used in its production, but the fact that there is no mention of water or the electrolysis procedure does not prevent the future adoption of new technologies.

In the same law, article 8 is amended to include the ANP's competences:

> XXXVI - to regulate, authorise and supervise activity in the hydrogen chain, including production, import, export, storage, stocking, standards for use and injection at delivery points or exit points."

It also places hydrogen in the context of national fuel supply, which is considered a public utility by Law No. 9.847/99, which provides for the supervision of activities relating to national fuel supply, as referred to in Law No.º 9.478/1997.

The last article of the Bill (Article 4) sought to guarantee the right of passage for green hydrogen through gas pipelines, establishing deadlines and percentages for starting this type of supply.

With the aim of promoting the use of hydrogen, the bill stipulates minimum percentages for the addition of hydrogen at entry and exit points of transport pipelines.

The project establishes that a minimum of 5 per cent hydrogen should be added to the gas pipeline network by 2032, and 10 per cent by 2050.

It then states that:

> §Paragraph 1 - The volume referred to in the heading must contain a mandatory proportion of sustainable hydrogen of at least 60 per cent in the case of item I and at least 80 per cent in the case of item II.
> §2º. The percentage referred to in the caput may be staggered incrementally in instalments, according to the security capacity of transport and supply.

It's worth noting that the new Gas Law and its regulating decree have established that "interchangeable gases" with natural gas, as in the case of hydrogen, will have regulatory treatment equivalent to natural gas. However, achieving these goals will certainly depend on the development of the hydrogen market and its technology.

BILL NO. 3.173/2023 - (FEDERAL SENATE)

(https://www25.senado.leg.br/web/atividade/materias/-/materia/158342)

Authored by Senator Marcos Pontes (PL-SP), Bill No. 3.173/2023 **establishes the so-called "Prohidroverde - National Green Hydrogen Programme"**, aimed at promoting the production, distribution and use of hydrogen generated from renewable energy sources. Article 1:

> Art. 1 Prohidroverde - National Green Hydrogen Programme - is hereby established to promote the production, distribution and use of hydrogen generated from solar, wind, biomass, biofuels, biodigesters, landfill gas and other renewable sources that may be created.

Prohidroverde, if approved, will have among its objectives:

- **promote the production of** clean energy, including, where applicable, through tax incentives and public financing at differentiated rates;
- **encourage research into** the development of clean energy;
- **create and structure** clean energy **study centres** throughout the country;
- **publicise the advantages of** using clean energy.

Senator Marcos Pontes' bill unfortunately does not provide what is expected of a regulatory framework, being **extremely generic and technically insufficient** to constitute a law that brings legal certainty to the nascent Brazilian green hydrogen market.
The bill will probably lose its object when more consistent bills move forward and are approved, leaving it to be shelved without being taken to the plenary sessions of the Federal Senate.

BILL NO. 2.308/2023 - (CHAMBER OF DEPUTIES)

(https://www.camara.leg.br/propostas-legislativas/2359608)

Bill 2.308/2023, authored by federal deputies Gilson Marques (Novo-SC) and Adriana Ventura (Novo-SP), is currently before the Chamber of Deputies. This bill provides for the **legal definition of Hydrogen Fuel and Green Hydrogen.**

The Bill proposes the inclusion of the definitions of hydrogen fuel and green hydrogen in the National Energy Policy Law (Law No. 9.478/1997), legislation that provides for national energy policy, activities relating to the oil monopoly and establishes the National Energy Policy Council and the National Petroleum Agency.

The Bill amends article 6 of Law 9.478/97, which establishes technical definitions for regulatory purposes. In this sense, it brings in the definitions of "hydrogen fuel", "green hydrogen", and "fuel cell system".

> XXXII - **Hydrogen Fuel:** hydrogen used as fuel in fuel cell systems, in engines or in other combustion processes, for the purposes of transport, heating, electricity generation and industrial applications, among other applications set out in regulations.
>
> XXXIII - **Green Hydrogen**: hydrogen fuel obtained from any process or technological route using renewable energy sources, such as water electrolysis, gasification of renewable biomass, biogas or biomethane reforming, glycerine reforming, co-product of biodiesel production, ethanol reforming, solar water photolysis, among other processes set out in regulations.
>
> XXXIV - **Fuel Cell System**: a complete set of components that produces electrical energy from the electrochemical reaction of a fuel, such as hydrogen, ethanol, natural gas or biomethane, among others, for use in vehicles or other applications.

The project's major innovation is the inclusion of the Fuel Cell System concept, which aims to conceptualise the energy production system for use in vehicles. However, it does not provide further details on relevant issues such as licences, the work of other regulatory agencies, environmental licensing and other aspects.

BILL NO. 3.452/2023 - (CHAMBER OF DEPUTIES)

(https://www.camara.leg.br/propostas-legislativas/2372982)

Bill No. 3.452/2023, authored by deputy Marcos Aurélio Sampaio (PSD-PI), "provides for the **concept of and incentives** for the energy use of hydrogen in Brazil", and also proposes changes to the text of Law No. 9.478/97, including the concept of sustainable hydrogen among national energy policies and establishing new definitions of hydrogen for energy use. The text of Article 6 would come into force with this wording:

> Art. 6 of Law 9.478/97.
>
> XXXII - **Hydrogen for energy use**: energy composed of hydrogen molecules, the result of different production routes, which can be used as a primary or secondary source, directly or indirectly, through the use of a fuel cell or other technology that may be developed;
>
> XXXIII - Sustainable hyd**rogen**: hydrogen for energy use produced through a process that results in low carbon production, under the terms of the regulations, and which may include different production routes.

The bill also gives the **National Agency for Petroleum, Natural Gas and Biofuels - ANP -** the power to standardise its use in the domestic market." According to the bill, the ANP will have the duty to "*regulate, authorise and inspect the activity of the hydrogen chain for energy use, including production, import, export, storage, stocking, standards for use and injection at delivery points or exit points", in line with other legislative initiatives*.

There is unanimity among the bills that the National Agency for Petroleum, Natural Gas and Biofuels (ANP) will be responsible for regulating, authorising and supervising the hydrogen chain in Brazil.

The bill also includes hydrogen-related initiatives in the provisions of Law No. 9.365/96, which provides for the remuneration of resources from the PIS-PASEP Participation Fund, the Workers' Support Fund and the Merchant Marine Fund, partly administered by the National Bank for Economic and Social Development (BNDES). The new proposal stipulates that the *BNDES* must invest at least 20% in projects involving the use of hydrogen as an energy source, under the terms of item XXXIII of art. 6 of Law no. 9478, of 6 August 1997.

INFRA-LEGAL LEGISLATION ON HYDROGEN IN BRAZIL

EXISTING HODROGEN-RELATED LEGISLATION IN BRAZIL

Brazil still doesn't have a regulatory framework and many definitions depend on the bills currently going through Congress, but as the Institute for Applied Economic Research (IPEA) explains in the aforementioned Panorama of Hydrogen in Brazil, some rules have already been approved on hydrogen in Brazil:

ABNT ISO/TR 15916: provides guidelines for the use of hydrogen in its gaseous and liquid forms, as well as its storage in one of these or other forms (hydrides). It identifies basic safety concerns, hazards and risks and describes the properties of hydrogen that are relevant to safety (ABNT, 2015).

ABNT NBR ISO 16110-1: deals with hydrogen generators using fuel processing technologies, applies to packaged, self-contained or factory-compatible hydrogen generation systems with a capacity of less than 400 m^3/h at 0 o C and 101.325 kPa, referred to in this standard as hydrogen generators, that convert an input fuel into a hydrogen-rich stream of suitable composition and conditions for the type of device that will utilise the hydrogen (e.g. a fuel cell type power generation system or a hydrogen compression, storage and distribution system).

ABNT NBR ISO 14687-1: hydrogen fuel - product specification - part 1: all applications except proton exchange membrane (PEM) fuel cells for self-propelled road vehicles (ABNT, 2010).

ABNT IEC/TS 62282-1: deals with fuel cell technologies (ABNT, 2007).

NBR IEC 62282-2: relating to fuel cell technologies - part 2: fuel cell modules providing the minimum requirements for the safety and performance of fuel cell modules.

NBR ISO 17268: deals with connection devices for refuelling land vehicles with hydrogen gas, applies to the verification of the design, safety and operation of connection devices for refuelling land vehicles with hydrogen gas (VTHG).

Resolution No. 5,947 of 1 June 2021 of the National Land Transport Agency (ANTT): on the transport of dangerous goods and the Chemical Safety Information Sheet, which updates the regulations for the transport of dangerous goods by road, approves its supplementary instructions, and makes other provisions.

Also according to IPEA, at the United Nations (UN) Ministerial Forum of the High-Level Dialogue on Energy 2021, the Brazilian government presented 02 government energy pacts, voluntary commitments on biofuels and hydrogen, as a national contribution to accelerating the fulfilment of the goals of Sustainable Development Goal 7 (SDG 7), which provides universal access to clean energy.

The year 2022 brought an important milestone affecting the hydrogen sector, which was the publication of **Decree No. 11.075 of 19 May 2022, creating the regulated carbon market in Brazil,** with a focus on exporting credits, particularly for countries and companies that need to offset emissions to meet their carbon neutrality commitments. Other Bills are currently in the pipeline that will deepen this regulation, notably Bill 412/2022, approved last week in the Federal Senate.

ANNEX – CHAPTER 3

7.12 1.1 ANNEX (1) - CORSIA SUSTAINABILITY CRITERIA FOR SUSTAINABLE AVIATION FUEL PRODUCED BY A CERTIFIED SUPPLIER

Table 8-4-1 CORSIA sustainability criteria for utilized SAF (extracted from [7])

THEME	PRINCIPLE	CRITERIA
1. Greenhouse gases	CORSIA SAF should generate lower carbon emissions on a life cycle basis	CORSIA SAF will achieve net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis.
2. Carbon stock	CORSIA SAF should not be made from biomass obtained from land with high carbon stock	CORSIA SAF will not be made from biomass obtained from land converted after 1 January 2008 that was primary forests, wetlands, or peat lands and/or contributes to degradation of the carbon stock in primary forests, wetlands, or peat lands as these lands all have high carbon stocks.
		In the event of land use conversion after 1 January 2008, as defined based on the Intergovernmental Panel on Climate Change (IPCC) land categories, direct land use change (DLUC) emissions will be calculated. If DLUC greenhouse gas emissions exceed the default induced land use change (ILUC) value, the DLUC value will replace the default ILUC value.
3. Water	Production of CORSIA SAF should maintain or enhance water quality and availability.	Operational practices will be implemented to maintain or enhance water quality.
		Operational practices will be implemented to use water efficiently and to avoid the depletion of surface or roundwater resources beyond replenishment capacities.
4. Soil	Production of CORSIA SAFs should maintain or enhance soil health.	Agricultural and forestry best management practices for feedstock production or residue collection will be implemented to maintain or enhance soil health, such as physical, chemical and biological conditions.
5. Air	Production of CORSIA SAF should minimize negative effects on air quality.	Air pollution emissions will be limited.
6. Conservation	Production of CORSIA SAF should maintain biodiversity, conservation value and ecosystem services.	CORSIA SAF will not be made from biomass obtained from areas that, due to their biodiversity, conservation value, or ecosystem services, are protected by the State having jurisdiction over that area, unless evidence is provided that shows the activity does not interfere with the protection purposes

THEME	PRINCIPLE	CRITERIA
		Low invasive-risk feedstock will be selected for cultivation and appropriate controls will be adopted with the intention of preventing the uncontrolled spread of cultivated alien species and modified microorganisms.
		Operational practices will be implemented to avoid adverse effects on areas that, due to their biodiversity, conservation value, or ecosystem services, are protected by the State having jurisdiction over that area.
7. Waste and Chemicals	Production of CORSIA SAF should promote responsible management of waste and use of chemicals.	Operational practices will be implemented to ensure that waste arising from production processes as well as chemicals used are stored, handled and disposed of responsibly.
		Responsible and science-based operational practices will be implemented to limit or reduce pesticide use.
8. Human and labour rights	Production of CORSIA SAF should respect human and labour rights.	CORSIA SAF production will respect human and labour rights.
9. Land use rights and land use	Production of CORSIA SAF should respect land rights and land use rights including indigenous and/or customary rights.	CORSIA SAF production will respect existing land rights and land use rights including indigenous peoples' rights, both formal and informal.
10. Water use and rights	Production of CORSIA SAF should respect prior formal or customary water use rights.	CORSIA SAF production will respect the existing water use rights of local and indigenous communities.
11. Local and social development	Production of CORSIA SAF should contribute to social and economic development in regions of poverty.	CORSIA SAF production will strive to, in regions of poverty, improve the socioeconomic conditions of the communities affected by the operation.
12. Food security	Production of CORSIA SAF should promote food security in food insecure regions.	CORSIA SAF production will, in food insecure regions, strive to enhance the local food security of directly affected stakeholders.

1.2 ANNEX 2: DEFAULT UPSTREAM AND STATIONARY COMBUSTION EMISSIONS OF DIFFERENT FUELS (EXTRACTED FROM [10])

Table 8-4-2 Default emissions factors for stationary combustion [gCO2eq/MJ]

Fuel	CO_2	CH_4	N_2O
Solid fossil fuels			
Anthracite	98.3	0.001	0.0015
Coking coal	94.6	0.001	0.0015
Other bituminous coal	94.6	0.001	0.0015
Sub-bituminous coal	96.1	0.001	0.0015
Lignite	101	0.001	0.0015
Patent fuel	97.5	0.001	0.0015
Coke oven coke	107	0.001	0.0015
Gas coke	107	0.001	0.0015
Coal tar	80.7	0.001	0.0015
Brown coal briquettes	97.5	0.001	0.0015
Manufactured gases			
Gas works gas	44.4	0.001	0.0001
Coke oven gas	44.4	0.001	0.0001
Blast furnace gas	260	0.001	0.0001
Other recovered gases	182	0.001	0.0001
Peat and peat products	106	0.001	0.0015
Oil shale and oil sands	73.3	0.003	0.0006
Oil and petroleum products			
Crude oil	73.3	0.003	0.0006
Natural gas liquids	64.2	0.003	0.0006
Refinery feedstocks	73.3	0.003	0.0006
Additive and oxygenates	73.3	0.003	0.0006
Other hydrocarbons	73.3	0.003	0.0006
Refinery gas	57.6	0.001	0.0001
Ethane	61.6	0.001	0.0001
Liquified petroleum gases	63.1	0.001	0.0001
Motor gasoline	69.3	0.003	0.0006
Aviation gasoline	70	0.003	0.0006
Gasoline-type jet fuel	70	0.003	0.0006
Kerosene-type jet fuel	71.5	0.003	0.0006
Other kerosene	71.5	0.003	0.0006

Fuel	CO_2	CH_4	N_2O
Naphtha	73.3	0.003	0.0006
Gas oil and diesel oil	74.1	0.003	0.0006
Fuel oil	77.4	0.003	0.0006
White spirit and SBP	73.3	0.003	0.0006
Lubricants	73.3	0.003	0.0006
Bitumen	80.7	0.003	0.0006
Petroleum Coke	97.5	0.003	0.0006
Paraffin waxes	73.3	0.003	0.0006
Other oil products	73.3	0.003	0.0006
Natural gas	56.1	0.001	0.0001
Waste			
Industrial waste (non-renewable)	143	0.03	0.004
Non-renewable municipal waste	91.7	0.03	0.004

Table 8-4-3 Default emissions factors for stationary combustion of fuels of biomass origin [gCO2eq/MJ]

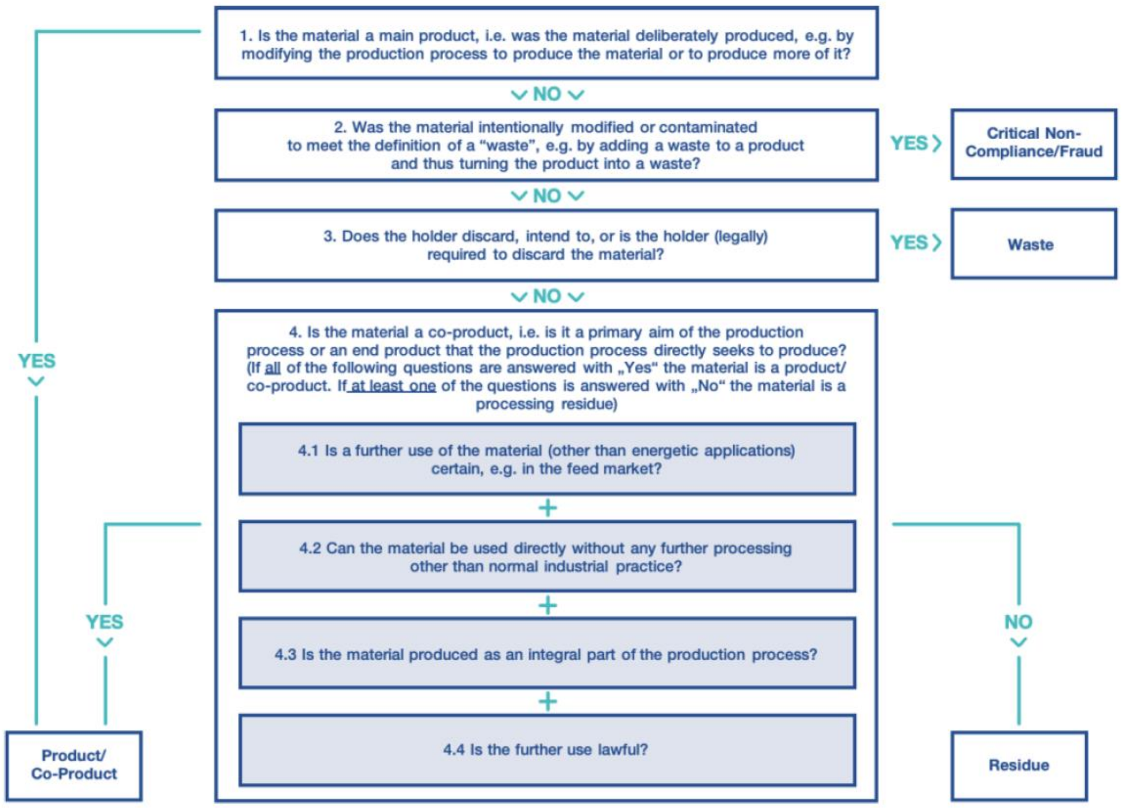
Fuel	CO_2	CH_4	N_2O
Primary solid biofuels	0	0.03	0.004
Charcoal	0	0.2	0.004
Biogases	0	0.001	0.0001
Renewable municipal waste	0	0.02	0.004
Pure biogasoline	0	0.003	0.0006
Blended biogasoline	0	0.003	0.0006
Pure biodiesels	0	0.003	0.0006
Blended biodiesels	0	0.003	0.0006
Pure bio jet kerosene	0	0.003	0.0006
Blended bio jet kerosene	0	0.003	0.0006
Other liquid biofuels	0	0.003	0.0006

Table 8-4-4 Fuel upstream emissions factors [gCO2eq/MJ]

Fuel	Emission factor
Hard coal	15.9
Brown coal	1.7
Peat	0

Fuel	Emission factor
Coal gases	0
Petroleum products	11.6
Natural gas	12.7
Solid biofuels	00.7
Liquid biofuels	46.8
Industrial waste	0
Municipal waste	0
Biogases	13.7
Nuclear	1.2

1.3 ANNEX 3: ASSESSMENT STEPS TO DETERMINE FEEDSTOCK QUALIFICATION UNDER ISCC EU [13]



1.4 ANNEX 4: ATTRIBUTES DESCRIPTION OF BIOFUELS, SAF AND EFUELS CERTIFICATION SYSTEMS [18]

Attribute of certification systems	Definition
GHG reduction and accounting methodology	How to calculate lifecycle greenhouse gas emissions and emissions targets.
Feedstock origin	What is the primary feedstock/energy source used for hydrogen production
Biodiversity Conservation	Operations avoid negative impacts on biodiversity, ecosystems, and conservation values.
Soil Conservation	Operations implement practices that seek to reverse soil degradation and/or maintain soil health.
Sustainable Water	Operations maintain or enhance the quality and quantity of surface and groundwater resources, and respect prior formal or customary water rights.
Air quality	Air pollution shall be minimised along the whole supply chain.
Community Development	In regions of poverty, operations contribute to the social and economic development of local, rural and indigenous people and communities.
Social aspects	Operations shall respect land rights and land use rights.
Labor conditions	Operations do not violate labour rights, and promote decent work and the well-being of workers.
Compliance with Laws and International Treaties	Operations follow all applicable laws and regulations.
Continous improvement	Sustainable operations are planned,implemented, and continuously improved
Additionality	That the renewable electricity used to produce hydrogen comes from a new generation plant (as not to compete with the production of clean energy for the grid).
Temp. Correlation	That the electricity used for the production of hydrogen is consumed in the same time frame in which it is generated (either days, hours or minutes).
Geogr. Correlation	That the renewable electricity used in the production of hydrogen is generated at a certain proximity to the hydrogen generation plant (e.g. same bidding zone).

ANNEX – CHAPTER 7

PROJECT FINANCE FROM A FINANCIER'S POINT OF VIEW

1. Project financing process

The process can basically be divided into the following phases:

- Preparation of the project by the project sponsors until the banks are approached
- Preliminary review of the project by banks, financing offer (term sheet)
- Acceptance of the financing offer, detailed project review, structuring of the financing, conclusion of all contracts
- Preparation for disbursement, start of construction, then start of operation
- Ongoing monitoring of the project until the end of the financing term or the project term.

1.2 Prior to bank contact

At the beginning of the process, before the sponsors (or their financial advisors) approach banks about possible project financing, they make their own decision as to whether they want to tackle the project in question.

It should be emphasized that when assessing a project approach, sponsors consider not only the "down-side" of a loss of the equity capital invested, but also and in particular the "up-side", i.e. above all the return for the company, or other positive effects for the company (such as entry into an attractive market). As a rule, a project must generate a predefined minimum return, which is usually in the low double-digit percentage range.

The following process steps are typical:

- Project idea, possibly in response to a call for proposals
- Internal review by sponsors
- Decision in principle to pursue the project
- Search for partners (e.g. co-sponsors, suppliers, consultants)
- Preparation of a business plan or feasibility study
- Internal approval process: preliminary green light to pursue the project further
- Approaching the banks
- Compilation of information for banks, possibly already with the support of external consultants.

1.3 After first contact with a bank

While sponsors judge a project primarily on its "up-side", banks look at the "down-side", i.e. the risks that can lead to a loan not being repaid properly or even defaulting completely. This perspective results from the fact that banks can only receive the maximum contractually agreed interest and fees. The banks do not participate if a project performs well economically but must expect losses if a project performs poorly economically.
In order to be able to assess whether a project is basically "bankable", banks require the following information, usually in the form of a business plan:
Parties involved (sponsors / investors, suppliers of the plant (if already known), buyers of the product [here: energy, hydrogen], government agencies, consultants, lawyers (annual financial statements for the last three years must be submitted for the main parties involved)):

- Technical description (technology, process, capacity, location)
- Existing infrastructure

- Specifically, RE projects: Yields (solar, wind, hydro)
- Specifically, hydrogen: sales market
- Key points of the project contracts (plant supply contract, purchase contracts [here: energy, hydrogen], input supply contracts)
- Timetables
- Economic and financial analysis: investment costs, operating costs, financial model with sensitivities, profitability indicators of the parties involved
- Feasibility study
- Financial model with projection over the entire project term ("banking case", i.e. a model specifically for the banks, "forward looking").

Once such an information package has been submitted, the process within the banks typically proceeds as follows:

- Initial screening of risks by banks and initial feedback to sponsors
- Rating of all relevant parties
- Preliminary internal financial model (based on the above-mentioned banking case)
- Preliminary term sheet (= financing offer)
- Negotiations Term Sheet.

This is followed by the sponsors and the banks:

- Compilation of the bank consortium by sponsors
- Joint preliminary term sheet of all banks in the consortium
- Assignment of roles to the individual consortium members on the bank side (e.g. consortium leader, technical agent, insurance agent, modelling agent).

1.4 After acceptance of offer

Once sponsors on the one hand and banks on the other have reached agreement, an intensive and time-consuming review, negotiation and authorization process begins:

- Detailed risk analysis by all parties involved, all sides have consultants
- Commissioning of external consultants and evaluation of their reports
- Detailed risk analysis
- Detailed financial model, sensitivities (down-side scenarios)
- Detailed term sheet
- Internal approval processes, any resulting adjustments to the term sheet
- Negotiation of project contracts and financing agreements
- Conclusion of all project and financing contracts.

1.5 After contract conclusion

The following activities are standard:

- Verification of disbursement requirements
- First disbursement (closing)
- Start of construction.

1.6 Construction and operating phase

During the construction and operating phases, the project is closely monitored by all parties involved on the basis of detailed reporting on the progress of the project by external consultants.

The financial model is updated on an ongoing basis. If predefined events occur (in particular if the debt service coverage ratios are not met), the banks are authorized to intervene.

H2UPPP: PRE-FEASIBILITY, BIOGAS TO HYDROGEN DERIVATIVES PRODUCTION IN PARANA, BRAZIL /TOLEDO

INPUT PROJECT TEASER

1 Introduction and Background

1.1 Background

GIZ has commissioned Niras to support the development of the mele biogas to Syncrude / Methanol.
The International Financial Consultant is charged to provide an input to the development of a teaser.
The report which has been drafted by Niras shall provide the basis for the teaser.
It should be noted that for a financier a project to finance as project finance lives from its revenues and only from its revenues. Therefore the "project" should present a business case for one product. Alternative products could be mentioned as an option.

1.2 Purpose of the teaser

The teaser shall provide a summarized overview on the project in all of its dimensions so as to allow banks and other financiers to appreciate the project and initiate the discussion.
The teaser shall be expanded during the further development of the project into a project memorandum and then into a full loan application. The later will obtain elements specific the requirements of the financial institution in question
Based on the a.m. TOR and within the framework of the assignment of the international consultant proposes the following elements for the teaser to be taken into account and provided. The following concentrates on the description of the project whereas other information important for the financiers shall also be provided with the "checklist" delivered separately by the int. financial consultant.

1.3 Structure of Teaser

The teaser shall contain the following information:

- Executive summary
- Information on the applicant / consortium of applicant
- Project description (see section 3 below)
- Implementation schedule (see section 4 below)
- Project financing (see section 5 below).

Whereas executive summary and information on the applicant should be self-explanatory the other parts of the project teaser are elaborated below.
Further documents can be added as they become available (e.g. LOI for offtake, results of financial model).

1.4 Project description

The project description must cover the entire value chain from the biogas input until the market and off-taker. Even if later on some parts of the value chain may obtain separate financing the logic of the financiers is to understand and evaluate the entire value chain.
The project description for the mele Biogas to Syncrude project should contain the following elements:

- Defining the product and value chain (several consecutive stages from slurry disposal over biogas production and hydrogen and syncrude production up to transport and marketing to offtaker(s))
- ESG Licensing requirements and government relations

Biogas

- Type and origin of inputs
- Biogas production

Renewable energy production

- Production: wind / solar
- Transport

Hydrogen production
Water supply
Methanol production
Reforming / Production of Syncrude / methanol / Fischer Tropsch, etc.
Infrastructure

- From farm to tanker,
- Geography
- Use of existing / new infrastructure.

Market

- ideally focusing on one product
- Off-taker: (international, national)

Financial analysis

- Levelized unit cost / to of product
- Project returns (IRR/NPV, debt service coverage)

Economic analysis and local value added
Macroeconomic benefits (local jobs, taxes, balance of payment effects / FX earnings etc.)
ESG

- Environmental
- Social
- Governance.

2 Implementation Schedule

Project development plan

- Technical planning
- Licensing
- Sales
- Financing of project development

Towards financial closing

- Establishment of SPV(s)
- Acquisition of private equity: project partners and third parties

After financial closing

- Key milestones
- Risks and mitigation strategies

3 Project financing

- The project's total financing requirements differentiated in Real and Euro
- Subsidies
- Basic financing structure
- Equity partners

- Debt financing

H2UPPP: PRE-FEASIBILITY, BIOGAS TO HYDROGEN DERIVATIVES PRODUCTION IN PARANA, BRAZIL /TOLEDO

CHECKLIST INFORMATION REQUIREMENTS

1 Introduction and Background

1.1 Background

Within the H2UPPP and H2 Brazil projects GIZ has commissioned Niras to support the development of the mele biogas to Syncrude / Methanol project.
The International Financial Consultant is charged to develop a checklist which shall allow the project sponsors to prepare the application to financial institutions.
In the following such a checklist is provided. It should be noted that there is a substantial difference between the commercial banks and the public banks – national banks or international financial institutions. Whereas commercial banks mainly look at the financial issues, i.e. the whole range of potential risks and the viability of the financing structure, the public financiers look in addition also on the economic impact on the national economy as well as socio economic aspects and environmental issues.
The requirements on those documents may differ from one IFI to another. Generally speaking the following needs to be prepared and presented.
In the following, "hydrogen" is used as a short cut for all products deriving from green hydrogen (e.g. synfuels, methanol, ammonia, etc.).

1.2 Documentation of the IPP's sponsors

For all the project sponsors the following documents should be made available:

- Experts from trade register
- Last three financial statements: Recent audited financial statements for the IPP's sponsors
- Business acumen: A summary of the IPP's sponsors' experience in the renewable energy & hydrogen industry and in Brazil
- Experience in managing complex projects: A summary of the IPP's sponsors' experience in managing large, complex projects
- Evidence of good track record in implementing similar projects in the targeted region and country; this could include a list of recently completed projects with testimonials from other co-financiers and beneficiaries as well as hyperlinks to relevant project completion and evaluation reports
- Proof of site relevant rights
- Land acquisition / lease
- Information on zoning land use and related permits.

1.3 Documentation of the IPP project

- Project description (project teaser / memorandum): A detailed description of the project, its various stages, including its location, size, technology, and expected revenue
- Detailed engineering designs and specifications (FEED)
- Slurry supply agreements
- Hydrogen purchase agreement (HPA): A copy of the HPA / LOI which is a contract between the IPP and the off-taker that guarantees the purchase of electricity at a certain price

- Technical feasibility study: A comprehensive study through the entire value chain that assesses the technical feasibility of the project, including the site assessment, resource assessment, environmental impact assessment, and grid connection plan
- Preliminary risk analysis: Technical risks both during construction and operation phase, with special attention the interface risks between the various project stages, supply risks, off-take risks, legal risks, financial risks, environmental and social risks.
- Financial model: A financial model that projects the project's revenue, expenses, and cash flows
- Technical and financial valid proposals from contractors, equipment manufacturers and other contractors and /or sub-contractors for the project
- Certification of the product as green hydrogen.

1.4 Commercialization

- Offtake agreements or letter of intent from potential buyers
- Alternative off-takes and off-takers.

1.5 Project development

Further planning

- Project development
- Project implementation

Further work and studies in progress

- Engineering (FEE)
- Studies (technical, legal, environmental and social, insurance)

Licensing

- List of permits needed
- Permits or description of current status of licensing process.

1.6 Management and Operational Plan

- Profiles of the project team, their experience, and credentials
- Operational plan including details of operation and maintenance (O&M) contractors, if any
- Evidence of available staff in the project country; this could include information on the number of experts employed and their qualifications
- Skills development plan.

4 Documentation of the IPP company (SPV)

At the stage of applying for a loan the SPV for the project should be established. The documentation on that SPV should include:

- Articles of association
- Evidence of currently valid legal registration under the laws of the country in which it is operating, as well as evidence of a certificate to do business in the country
- List and profiles of Members of the Board of Directors'
- CVs of Managing Directors
- Board of Directors meeting minutes: Minutes of recent board meetings that discuss the company's financial performance and plans
- Business plan: A comprehensive business plan that outlines the company's strategy, target markets, financial projections, and management team

- Audited company financial statements: Recent financial statements for the IPP and its parent company, including the balance sheet, income statement, and cash flow statement
- Letter of intent from investors: Letters of intent from investors who have committed to investing in the project equity or debt
- Tax returns: Recent tax returns for the IPP and its parent company.

5 Environmental Social and Governance (ESG)

Especially for the public IFIs but also increasingly for private financiers ESG becomes increasingly important. The following types of documents will typically need to be provided:

- Environmental and social management or commitment plan ("ESMP"/"ESCP")
- Environmental permits: Any environmental permits that are required for the project
- Studies and plans regarding local value added, community development, etc.
- Compliance rules and regulations and compliance management plan
- Letters of support or LOI from public institutions
  - National
  - Provincial
  - Local
  - Infrastructure related (utility, port authorities, etc.).

6 Additional documents

- Grid connection approval: Approval from the grid operator to connect the project to the grid
- Insurance documentation: Insurance documentation that covers the project's assets and operations
- Project Proposal or Business Plan
- Detailed description of the project, including technology to be used, project location, and scale
- Project development and construction plan, including timelines and key milestones
- Due Diligence Reports: Reports from third-party due diligence on various aspects of the project (technical, legal, financial).

- Financial documents:
  - Detailed cost breakdown, including capital expenditure (CAPEX) and operational expenditure (OPEX)
  - Projected cash flows, revenue models, and profitability analysis
  - Information on the equity and debt structure, including the amount of own capital invested and the amount and terms of debt required.

- Environmental and Social Impact Assessments (ESIA):
  - Reports detailing the environmental impact of the project and mitigation strategies
  - Social impact assessment and community engagement plans.
  - Risk Analysis and management:
  - Identification and assessment of project risks (construction risks, operational risks, market risks, etc.) and their mitigation strategies
  - Insurance and risk management strategies
  - LOIs of insurance companies
  - Technical industrial Political (ECAs)

  .

- Legal and Regulatory Documents:

- Permits and approvals from relevant authorities (e.g., environmental permits, construction permits)
- Power Purchase Agreements (PPA), grid connection agreements, or off-take agreements.
- Land lease agreements or land ownership documents
- Incorporation documents and details of the project company's legal structure.
- Market and Industry Analysis:
- Analysis of the renewable energy market, policy landscape, and regulatory incentives
- Information on competitors and market demand.

2 Management and operational plan

- Profiles of the project team, their experience, and credentials
- Operational plan including details of operation and maintenance (O&M) contractors, if any.
- Evidence of available staff in the project country; this could include information on the number of experts employed and their qualifications.

H2UPPP: PRE-FEASIBILITY, BIOGAS TO HYDROGEN DERIVATIVES PRODUCTION IN PARANA, BRAZIL /TOLEDO

INPUT TO FINANCIAL MODELLING

1 Introduction and Background

Within the H2UPPP and H2 Brazil projects, GIZ has commissioned Niras to support the development of the mele biogas to Syncrude / Methanol.
The International Financial Consultant is charged to develop an input for the financial modelling which has been contracted separately by GIZ.
In the following such a checklist is provided. It should be noted that there is a substantial difference between the commercial banks and the public banks – national banks or international financial institutions. Whereas commercial banks mainly look at the financial issues, i.e. the whole range of potential risks and the viability of the financing structure, the public financiers look in addition also on the economic impact on the national economy as well as socio economic aspects and environmental issues.
The requirements may differ from one IFI or financier to another but should contain the elements developed below.
It shall be noted that the requirements developed below are mainly for the local financial consultant charged with the financial modelling.
Depending on the financing structure and financiers to be approached this will require to be further refined in the process to achieve financial closing.

2 Methodological

The methodological requirements shall be summarized as follows:

- Open MS Excel system
- Full documentation of:
  - Model structure incl. flow chart
  - Assumptions
  - VBA Macros if any

- Clear marking of cells of Input, Calculation and Output
- Modular structure
  - Subprojects for parts of the value chain e.g.:
    - Biogas
    - Renewable energy
    - H2 from electrolysis
    - Water production
    - Methane production
    - Transport

  - Separate financing module accounting for:
    - Uses and Sources of Funds
    - Equity
    - Debt differentiated by separate tranches maturity, currency and interest
    - Mezzanine financing
    - Interest and financing during construction
    - Operational capital
    - Taxes and subsidies

  - Project development phase:
    - External cost
    - Project developer's cost

    - User friendliness
      - Synthesis (e.g. total CAPEX, OPEX and revenues)
      - Cockpit to see key inputs and their impact on outputs on one screen

Consistency checks: Conditional formatting can be used to highlight cells that contain inconsistent data

.

For example, you could use conditional formatting to highlight cells that contain negative values I revenue or profit calculation. This can help you identify potential errors in your model early on.

Data validation can be used to restrict the type of data that can be entered into cells. For example, you could use data validation to ensure that only numeric values are entered into cells that represent financial amounts. This can help to prevent errors caused by typos or data entry mistakes.

Error trapping can be used to detect and handle errors that occur in your model. For example, you could use error trapping to prevent division by zero errors. This can help to prevent your model from crashing and to ensure that you receive meaningful results.

Multiple methods shall be used to check for consistency

Documentation of consistency checks.

3 Input

The input parameters of the financial model for mele Biogas to Syncrude project should be implemented as follows:

- Project summary sheet

- Project name
- Project location
- Project technology
- Project capacity
- Project expected output

- Uses and sources of funds
- Capex
  - According to timeline during construction
  - In Real and Euro

- Revenues
  - Different revenue streams
  - Alternative products and their revenue streams

- Operation Cost
- Origin / assumption for every variable
- Risks / unforeseen / sensitivity analysis based on potential risks, e.g.
  - Delay of construction time
  - Increase in construction cost (% of CAPEX)
  - Increase in supply cost
  - Increase in other production cost
  - Decrease in capacity utilisation
  - Decrease in output prices.

4 Output

The financial model should from the data it contains calculate and nicely present the following output:
Financial metrics, on project economics and financial viability such as:

- Net present value (NPV)
- Internal rate of return (IRR)
- Debt Service coverage ratio (DSCR)

- Levelized cost of product (e.g. € / kg)
- Scenario analysis
  - Base case
  - Best case
  - Worst case

- Sensitivity analysis
- Financial statement of SPV
  - P&L
  - Balance sheet
  - Cash flow statement

- Basic financing structure
- Equity partners
- Debt financing
- Visualization / graphs

- Sensitivity analysis
- Scenario analysis
- Pie charts (e.g. cost break down).

5 Conclusion and Recommendation

- Summarize the key findings of the financial model
- Provide a clear recommendation on whether to proceed with the project financing
- Identify any additional information or analysis that may be required.

APPENDIX A – CHAPTER 2

1. STEAM METHANE REFORMING – KINETIC MODELING

To perform the steam methane reforming and convert this compound into synthesis gas, a kinetic model was studied. The work presented by Xu and Froment (1989) brings the rate equations for the steam reforming of methane, accompanied by water-gas shift and the reverse methanation on a $Ni/MgAl_2O_4$ catalyst. The authors use different operational conditions of temperature, pressure, amount of catalyst and steam to methane ratio to study different conditions. The modeling equations and parameters were adjusted by the authors using the LHHW kinetic model. It can be described in a generalized model as:

$$r = \frac{(kinetic\ factor) \cdot (driving\ force)}{(adsorption)} \tag{5}$$

The individual terms are given by:

$$kinetic\ factor = k_{0i} \cdot e^{(-\frac{E_a}{R \cdot T})} \tag{6}$$

$$driving\ force = K_1(\prod C_i^{\nu_i}) - K_2(\prod C_i^{\nu_i}) \tag{7}$$

$$adsorption = \left[\sum K_i(\prod C_i^{\nu_i})\right]^m \tag{8}$$

Where k_{0i} is the kinetic pre-exponential factor, Ea is the activation energy, T is the absolute temperature, R is the universal gas constant, C_i is the concentration of component i, ν_i is the exponent of component i, and m is the exponent of the adsorption term. The terms K_1, K_2, and K_i are constants that may depend on the temperature of the system. This dependence can be expressed as follow, where A, B, C, and D are constants.

$$\ln K_i = A + \frac{B}{T} + C\ ln\ T + DT \tag{9}$$

There are three main reactions that take place into the steam methane reforming process, as presented in Table 2.2. Each reaction in the system can be described by a rate expression, incorporating kinetic, driving force, and adsorption terms. The following equations were used to evaluate the system, with rate values calculated in kmol/kg cat.h and all partial pressures (pi) estimated in bar.

$$r_1 = \frac{k_1 \cdot \left(\frac{p_{CH4} \cdot p_{H2O}}{p_{H2}{}^{2,5}} - \frac{p_{H2}{}^{0,5} \cdot p_{CO}}{K_1}\right)}{(DEN)^2} \tag{10}$$

$$r_2 = \frac{k_2 \cdot \left(\frac{p_{CO} \cdot p_{H2O}}{p_{H2}} - \frac{p_{H2} \cdot p_{CO2}}{K_2}\right)}{(DEN)^2} \tag{11}$$

$$r_3 = \frac{k_3 \cdot \left(\frac{p_{CH4} \cdot p_{H2O}{}^2}{p_{H2}{}^{3,5}} - \frac{p_{H2}{}^{0,5} \cdot p_{CO2}}{K_3}\right)}{(DEN)^2} \tag{12}$$

$$DEN = 1 + K_{CO}p_{CO} + K_{H2}p_{H2} + K_{CH4}p_{CH4} + \frac{K_{H2O}p_{H2O}}{p_{H2}} \tag{13}$$

- Kinetic factor

The rate expressions begin with the kinetic factor, represented by k_1, k_2, and k_3. These values were calculated using the equation provided in Table 8.5, along with all of the necessary parameters.

Table 8-4-5 Kinetic Factors for SMR.

Nº	k_i		k_{0i}	Ea (kJ/mol)	Tr (K)
r1	$k_i = k_{0i} \cdot e^{\left(\frac{-Ea}{R}\right)\cdot\left(\frac{1}{T}-\frac{1}{Tr}\right)}$	$kmol.bar^{0,5}/kg.h$	$1,84.10^{-4}$	240,1	648
r2		kmol/bar.kg.h	7,558	67,13	648
r3		$kmol.bar^{0,5}/kg.h$	$2,19.10^{-5}$	243,9	648

- Driving Force
  In support of the driving force analysis, the Ki equations were also provided, shown below. The temperature T was used in K. For mathematical convenience, all expressions were transformed into logarithmic form, as demonstrated in Equation 5.

$$K_1 = \exp\left(\frac{-26830}{T} + 30.114\right) \quad [bar^2] \tag{14}$$

$$K_2 = \exp\left(\frac{4400}{T} - 4.063\right) \quad [-] \tag{15}$$

$$K_3 = K_1 \times K_2 \quad [bar^2] \tag{16}$$

- Adsorption
  Additionally, the authors reported the adsorption terms, provided below. These terms were also converted into logarithmic form for necessary calculations. The temperature T is in Kelvin (K) and the gas constant R is 0.008314 kJ/mol.K.

$$K_{CH4} = 6.65 \cdot 10^{-4} \exp\left(\frac{38280}{RT}\right) \quad [bar^{-1}] \tag{17}$$

$$K_{H2O} = 1.77 \cdot 10^{5} \exp\left(\frac{-88680}{RT}\right) \quad [-] \tag{18}$$

$$K_{CO} = 8.23 \cdot 10^{-5} \exp\left(\frac{70650}{RT}\right) \quad [bar^{-1}] \tag{19}$$

$$K_{CO} = 6.12 \cdot 10^{-9} \exp\left(\frac{82900}{RT}\right) \quad [bar^{-1}] \tag{20}$$

The kinetic model proposed by Xu and Froment (1989) was validated using the same operational conditions reported in their original research. The validation was performed under a pressure of 10 bar and a steam-to-methane ratio of 3. Different values for the system temperature were used to evaluate the effectiveness of the kinetic model. The validation results are shown in Figure 2.2.

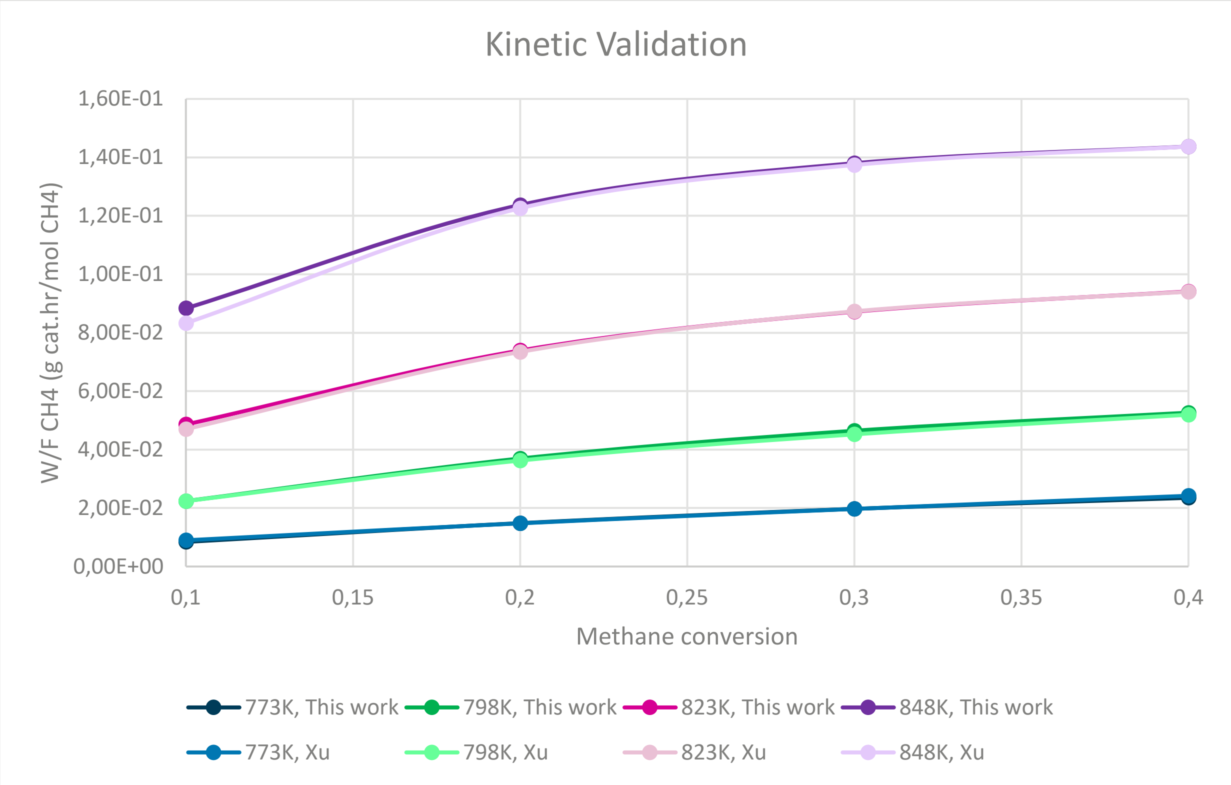


Figure 8-4-1 Kinetic Validation for Steam Methane Reforming based on Xu and Froment (1989).

2. METHANOL SYNTHESIS – KINETIC MODELING

Similar to the process of steam methane reforming, a kinetic model was investigated for converting syngas into methanol (CH_3OH). The work presented by (Bisotti et al., 2021) details the rate equations for methanol production, building upon Graaf's (1988) kinetic model for CH_3OH synthesis (Graaf et al., 1988). This model is considered more robust and comprehensive due to its consideration of both CO and CO_2 hydrogenation alongside the reverse water-gas shift (RWGS) reaction. Additionally, the authors employ lower pressures when modeling the rate expressions and utilize a Cu-Zn-Al catalyst. The modeling equations and parameters were adjusted using the LHHW kinetic model, which was also employed in the SMR kinetics.

$$r = \frac{(kinetic\ factor) \cdot (driving\ force)}{(adsorption)} \tag{21}$$

The individual terms are given by:

$$kinetic\ factor = k_{0i} \cdot e^{(-\frac{E_a}{R \cdot T})} \tag{22}$$

$$driving\ force = K_1(\prod C_i^{\nu_i}) - K_2(\prod C_i^{\nu_i}) \tag{23}$$

$$adsorption = \left[\sum K_i(\prod C_i^{\nu_i})\right]^m \tag{24}$$

Where k_{0i} is the kinetic pre-exponential factor, Ea is the activation energy, T is the absolute temperature, R is the universal gas constant, C_i is the concentration of component i, ν_i is the exponent of component i, and m is the exponent of the adsorption term. The terms K_1, K_2, and K_i are constants that may depend on the temperature of the system. This dependence can be expressed as follow, where A, B, C, and D are constants.

$$\ln K_i = A + \frac{B}{T} + C \ln T + DT \qquad (25)$$

There are three main reactions that take place into the syngas conversion to methanol, as presented in Table 2.7. Each reaction in the system can be described by a rate expression, incorporating kinetic, driving force, and adsorption terms. The following equations were used to evaluate the system, with rate values calculated in kmol/kg cat.h and all partial pressures (pi) estimated in bar.

$$r_1 = \frac{k_1 \cdot \left(K_{CO2} \cdot p_{CO2} \cdot p_{H2}{}^{1,5} - \frac{K_{CO2} \cdot p_{MeOH} \cdot p_{H2O}}{p_{H2}{}^{1,5} \cdot K_{eqCO2}} \right)}{DEN} \qquad (26)$$

$$r_2 = \frac{k_2 \cdot \left(K_{CO2} \cdot p_{CO2} \cdot p_{H2} - \frac{K_{CO2} \cdot p_{H2O} \cdot p_{CO}}{K_{eqRWGS}} \right)}{DEN} \qquad (27)$$

$$r_3 = \frac{k_3 \cdot \left(K_{CO} \cdot p_{CO} \cdot p_{H2}{}^{1,5} - \frac{K_{CO} \cdot p_{MeOH}}{p_{H2}{}^{0,5} \cdot K_{eqCO}} \right)}{DEN} \qquad (28)$$

$$DEN = (1 + K_{CO}p_{CO} + K_{CO2}p_{CO2}) \cdot (p_{H2}{}^{0,5} + \frac{K_{H2O}p_{H2O}}{K_{H2}{}^{0,5}}) \qquad (29)$$

- Kinetic factor
  The rate expressions begin with the kinetic factor, represented by k_1, k_2, and k_3. These values were calculated using the equation provided in Table 2.8, along with all of the necessary parameters.

Table 8-4-6 Kinetic factors for Methanol production.

Nº	k_i	k_{0i}	Ea (kJ/kmol)
r1	$k_i = k_{0i} \cdot e^{\left(\frac{-Ea}{RT}\right)}$	$1{,}09.10^{5}$	87,500
r2		$9{,}64.10^{11}$	152,900
r3		$4{,}89.10^{7}$	113,000

- Driving Force
  In support of the driving force analysis, the Ki equations were also provided, shown below. The temperature T was used in K. For mathematical convenience, all expressions were transformed into the natural logarithmic form (ln), as demonstrated in Equation 5.

$$\log_{10} K_{eqCO2} = \frac{3066}{T} - 10.592 \quad [bar^{-2}] \qquad (30)$$

$$\log_{10} K_{eqRWGS} = -\frac{2073}{T} + 2.029 \quad [-] \tag{31}$$

$$\log_{10} K_{eqCO} = \frac{5139}{T} - 12.621 \quad [bar^{-2}] \tag{32}$$

- Adsorption

  Additionally, the authors reported the adsorption terms, provided below. These terms were also converted into logarithmic form for necessary calculations. The temperature T is in Kelvin (K) and the gas constant R is 0.008314 kJ/mol.K.

$$K_{CO2} = 7.05 \cdot 10^{-7} \exp\left(\frac{61700}{RT}\right) \tag{33}$$

$$K_{CO} = 2.16 \cdot 10^{-5} \exp\left(\frac{46800}{RT}\right) \tag{34}$$

$$K_{H2O} / {K_{H2}}^{0,5} = 6.37 \cdot 10^{-9} \exp\left(\frac{84000}{RT}\right) \tag{35}$$

The effectiveness of the kinetic model proposed by Graff (1988) was assessed under identical operating conditions as described in his original research. The validation was conducted at 250 °C using a bio-syngas feedstock of 50 kmol/h. Different system pressures were evaluated to gauge the model's accuracy. The validation results are presented in Figure 8.4.2.

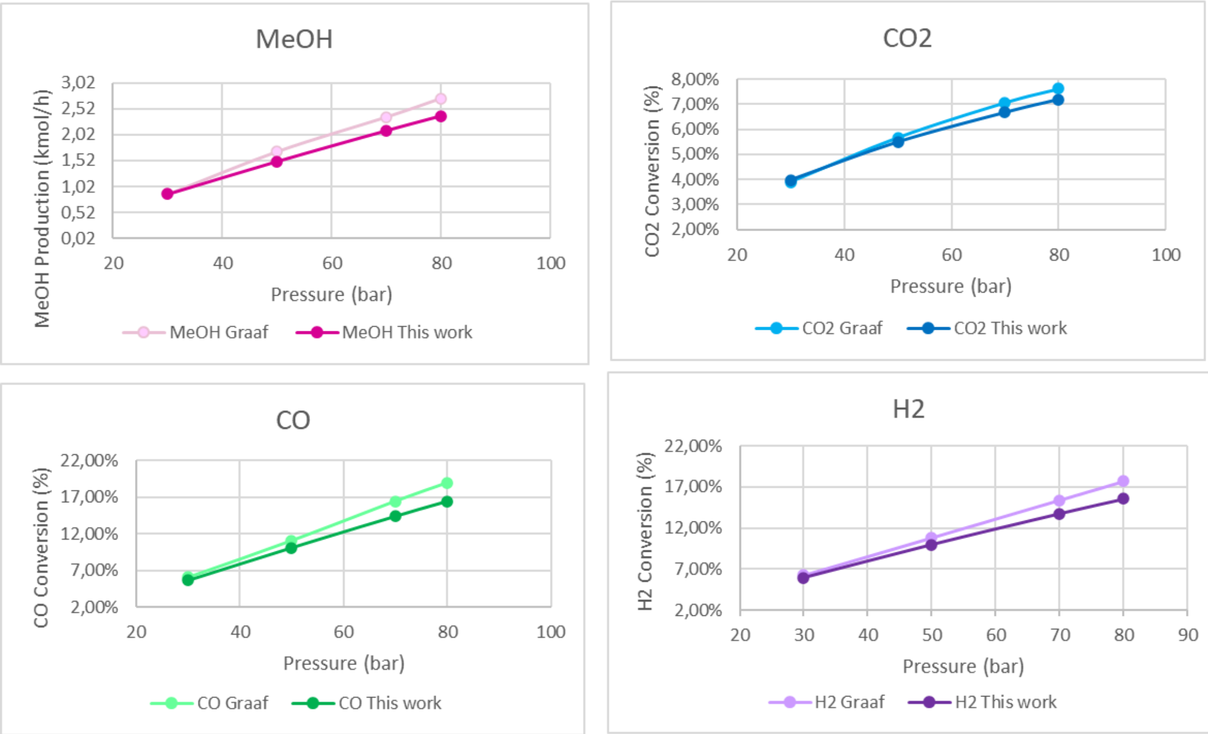


Figure 8-4-2 Kinetic validation for methanol synthesis based on (Graaf et al., 1988).

3. FT PRODUCT FORMATION RATES – KINETIC MODELING

As previously mentioned, the kinetic modeling equations were derived from the CO-insertion mechanism. The main equations used in the product formation rates will be presented. For further detail refer to (Todic et al., 2014).

- Weak Van Der Waals interactions related constant:

$$c = -\frac{\Delta E}{RT} \tag{36}$$

- Chain growth probabilities:

$$\alpha_1 = \frac{k_3K_1P_{CO}}{k_3K_1P_{CO} + k_{7M}\sqrt{K_2P_{H2}}} \tag{37}$$

$$\alpha_2 = \frac{k_3K_1P_{CO}[S]}{k_3K_1P_{CO}[S] + k_7\sqrt{K_2P_{H2}}[S] + k_{8,E}e^{2c}} \tag{38}$$

$$\alpha_n = \frac{k_3K_1P_{CO}[S]}{k_3K_1P_{CO}[S] + k_7\sqrt{K_2P_{H2}}[S] + k_{8,0}e^{nc}} \quad n \geq 3 \tag{39}$$

- Site balance (void site fraction):

$$[S] = \frac{1}{1 + K_1 P_{CO} + \sqrt{K_2 P_{H_2}} + \left(\frac{1}{K_2^2 K_4 K_5 K_6} \frac{P_{H_2O}}{P_{H_2}^2} + \sqrt{K_2 P_{H2}}\right)\left(\alpha_1 + \alpha_1 \alpha_2 + \alpha_1 \alpha_2 \sum_{i=3}^{n} \prod_{j=3}^{i} \alpha_j\right)} \tag{40}$$

- Hydrocarbon formation rates:

$$R_{CH_4} = k_{7M} K_2^{0.5} P_{H_2}^{0.5} \alpha_1 [S]^2 \tag{41}$$

$$R_{C_nH_{2n+2}} = k_7 K_2^{0.5} P_{H_2}^{0.5} \alpha_1 \alpha_2 \prod_{i=3}^{n} \alpha_i [S]^2 \quad n \geq 2 \tag{42}$$

$$R_{C_2H_4} = k_{8E,0} e^{2c} \alpha_1 \alpha_2 [S] \tag{43}$$

$$R_{C_nH_{2n}} = k_{8,0} e^{nc} \alpha_1 \alpha_2 \prod_{i=3}^{n} \alpha_i [S] \quad n \geq 3 \tag{44}$$

- Kinetic and equilibrium constants:

$$k_i(T) = A_i \exp\left(-\frac{E_{a,i}}{RT}\right) \tag{45}$$

$$K_i(T) = A_i \exp\left(-\frac{DH_i}{RT}\right) \tag{46}$$

A_i, E_i, DH_i, DE – Parameters estimated by the authors using the model equations and the experimental data obtained by Todic et al. (2014).
R – Gas constant;
T – Temperature;
k_i – Kinetic constants;
K_i – Equilibrium constants;
n – carbon numbers in the considered hydrocarbon chain;
c – weak Van Der Waals interactions related constant;
a_i – Chain growth probabilities;
[S] – void catalytic sites faction;
P_i – Partial pressure.

The parameters fitted by the authors are provided in Table 8.7.

Table 8-7 Kinetic parameters for FT synthesis – from Todic et al. (2014) model.

Parameter (unit)	Value	Parameter (unit)	Value	Parameter (unit)	Value
A_1 (MPa^{-1})	6.59×10^{-5}	A_8 (mol/g_{cat}.h)	4.11×10^{8}	DH_4 (kJ/mol)	16.2
A_2 (MPa^{-1})	1.64×10^{-4}	A_7 (mol/g_{cat}.h)	7.35×10^{7}	DH_5 (kJ/mol)	11.9
A_3 (mol/g_{cat}.h)	4.14×10^{-8}	A_{8E} (mol/g_{cat}.h)	4.60×10^{7}	DH_6 (kJ/mol)	14.5

A_4 (-)	3.59x10^5	DE (kJ/mol/CH_2)	1.1	E_7 (kJ/mol)	75.5
A_5 (-)	9.81x10^{-2}	DH_1 (kJ/mol)	-48.9	E_8 (kJ/mol)	100.4
A_6 (MPa)	1.59x10^6	DH_2 (kJ/mol)	-9.4	E_{7M} (kJ/mol)	65.4
A_7 (mol/g_{cat}.h)	4.53x10^7	E_3 (kJ/mol)	92.8	E_{8E} (kJ/mol)	103.2

Adapted from: (Todic et al., 2013).

Once the reactor inlet operating conditions are known (temperature, pressure, reactants mole fractions), the kinetic and equilibrium constants can be calculated. To calculate the hydrocarbon formation rates, the values of a and [S] must be known. [S] is an implicit function of a, and therefore a numerical method is required to solve this equation iteratively. The *regula falsi* method was chosen and the [S] equation was solved in the 0-1 interval. Once the temperature and partial pressures are modified in the simulation, [S] and a need to be recalculated since they are function of those variables.

Once the values of [S] and a are obtained for a specific experimental condition (reactants mole fraction, temperature, pressure, and number of considered carbon chains), the product formation rates calculations are straightforward. As previously mentioned, carbon chains of up to 30 carbons were considered for both 1-parafins and 2-olefins. Therefore, the 59 hydrocarbon formation reactions were implemented, each one with its own calculated formation rates depending, among other factors, on the carbon chain number. With the reactor operating conditions known and the kinetics implemented, all the necessary information required to model the FT reactor is given. At this first moment, the heat released by the FT reactor was not considered either for heat integration or for utility consumption purposes. The hydrocarbon formation rates are dependent on the catalyst mass. Considering 65 % as a usually reported CO conversion for FTS, the catalyst mass was adjusted to fit these conversion values.

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