IFAISTOS

Intelligent electroFuel production for An Integrated STOrage System

Deliverable

7.1 - Report on the definition of the scalable design methodology

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Executive summary

The IFAISTOS project embarks on an exploratory research into the ever-evolving landscape of modern energy technologies and solutions, with a resolute objective of achieving a sustainable "Power-to-Gas" (PtG) transformation. At its core, the project seeks to leverage the power of renewables, from all the different resources like, solar, wind, biogas, hydrogen and different storage solutions, and CO_2 capture to craft an innovative technical configuration capable of generating synthetic methane while fostering environmental stewardship. This comprehensive deliverable serves as a record of all the research done by the different figures involved in the technical modeling of the solution with the economical analysis and moreover with the planification of pilot projects.

The mission is to select the most fitting technical configuration that aligns with the PtG objectives starting with an analysis of all the available renewable resources in the market. At the core of the project lies the electrolysis process, which allows converting renewable energy into green hydrogen. It can be stored and used to produce synthetic methane from recovered CO_2 from boiler flue gas.

In addition, along with generation, the efficiency of energy storage systems is also important to ensure continuous operation of the PtG system even if the renewable energy source produces energy with significant fluctuations throughout the day and year. The technologies analyzed in this analysis include hydrogen storage and battery power storage systems.

PtG facilities include CO_2 capture systems, moving in the direction of mitigating climate change by diverting carbon dioxide emissions from industrial processes by turning it into valuable resources. Exploring opportunities in the food sector by capitalizing on the demand for liquefied CO_2 further promotes the principles of circular economy and sustainability.

In the following paper, a methodology for technical-economic evaluation of a power-to-gas project has been analyzed. The first phase consists of a qualitative assessment of the project that determines the proximity to Siram's core business and the evaluation of all critical factors of the technical solutions to be adopted. The second phase consists of the use of simulation tools for modeling the different possible plant configurations to obtain: an estimate of the initial cost (Capex), the operating cost (Opex) of the plant, the savings with respect to the situation in which PtG solution is not implemented and the revenues that can be obtained when the plant is active.

This deliverable is a testament to the collective pursuit of progress, innovation, and environmental stewardship. The project aims to offer a roadmap for a more sustainable, reliable, and resilient energy future. The pages that follow will unveil the complexities of the analysis, shedding light on the multifaceted facets of the PtG solution, its technical intricacies, and its potential to redefine the energy paradigm.

1. Introduction

The IFAISTOS project embarks on a transformative research into the dynamic and ever-evolving landscape of modern energy technologies and solutions. With unwavering determination, this project has set forth a clear and resolute objective: to usher in a sustainable "Power-to-Gas" (PtG) transformation. Rooted in the profound belief that innovation, sustainability, and environmental stewardship must guide the path, the IFAISTOS project ventures to harness the potential of renewable resources, encompassing a diverse spectrum from solar and wind to biogas and hydrogen. This expansive initiative further incorporates storage solutions and CO_2 capture mechanisms to engineer a visionary technical configuration capable of producing synthetic methane, all while aligning with the unwavering commitment to a greener future.

In the realm of modern energy, the IFAISTOS project represents an attempt at innovation, driven by a mission to harness the full potential of emerging technologies. The commitment to this mission is reflected not only in the aspiration to craft a sustainable PtG solution but also in the comprehensive approach taken to research, analyze, and model this intricate energy system.

➢ 1.1 The Imperative for PtG Transformation

The imperative for a PtG transformation is both compelling and urgent. With global energy demand surging and the environmental repercussions of fossil fuel consumption becoming increasingly evident, society stands at a critical juncture. As traditional energy faces depletion and concerns over greenhouse gas emissions grow, the IFAISTOS project aligns itself with the transition toward cleaner and more sustainable energy systems. (Smith, 2021)

The PtG concept offers a profound solution. By converting surplus renewable energy into synthetic methane, we bridge the gap between intermittent renewable sources and the consistent energy supply demanded by industries and communities. This approach not only promises to enhance energy security but also holds the potential to reduce carbon emissions significantly, contributing to global climate change mitigation efforts. Moreover, the project's focus on circular economy principles underscores the commitment to resource efficiency and sustainability. (International Energy Agency, 2020)

➢ 1.2 Scope of the Deliverable

This deliverable serves as a comprehensive record of the extensive research, technical modeling, economic analysis, and strategic planning undertaken within the IFAISTOS project. It unfolds a roadmap that guides us through the details of the PtG initiative, illustrating the dedication to innovation and sustainability.

➢ 1.3 Structure of the Deliverable

To navigate this document effectively, it is essential to understand its structure. The deliverable is organized into distinct sections, each illuminating a critical facet of the PtG transformation research:

- **Section 2 Power-to-Gas Economical Context:** In this section, we delve into the broader economic context of the PtG transformation. We examine the economic drivers, challenges, and opportunities that influence the adoption of PtG technologies. By providing a comprehensive overview of the economic landscape, we set the foundation for understanding the financial aspects of the project.

- **Section 3 Veolia's Target and Commitment:** Veolia's commitment to sustainability and environmental stewardship is paramount. In this chapter, we elucidate Veolia's specific targets and objectives within the PtG domain. We explore how the project aligns with Veolia's overarching sustainability goals and corporate mission.

- **Section 4 Market Analysis of Services and Suppliers:** A thorough market analysis is crucial to understanding the landscape in which the PtG project operates. In this section, we assess the market for PtG services and suppliers. We identify key players, analyze market trends, and evaluate the competitive landscape to inform the project strategy.

- **Section 5 Technology Evaluation Methodology:** Core of the PtG initiative lies in technology. In this chapter, we outline the methodology used for evaluating PtG technologies. We define criteria, metrics, and assessment techniques to ensure a rigorous and objective evaluation process.

- **Section 6 Business Model Evaluation:** A sustainable PtG solution requires a sound business model. This section delves into the business models underpinning the project. We assess their viability, scalability, and alignment with economic objectives.

- **Section 7 Model and System Configurations:** The core of the deliverable lies in modeling and system configurations. In this chapter, we detail the technical aspects of the PtG system, exploring different configurations, process models, and simulation tools used in the analysis.

- **Section 8 Conclusion:** This section synthesizes the findings, offering a comprehensive view of the IFAISTOS PtG initiative and its implications. We conclude with a glimpse into the future and the potential for a more sustainable and reliable energy landscape.

2. Power-to-Gas Economical Context

The Power-to-Gas (PtG) sector has emerged as a promising solution within the broader context of renewable energy and sustainable power generation. Due to the global transition towards renewable energy sources, such as solar and wind, has gained significant momentum in recent years. As highlighted by the International Energy Agency (IEA) in their "Renewables 2020: Analysis and Forecast to 2025" report (2020), the share of renewable energy in the global energy mix continues to increase. This transition needs efficient energy storage solutions to manage the intermittent nature of renewables, creating a fertile ground for PtG applications.

On the other hand, this huge penetration of renewable energies faces an ongoing challenge for grid operators and energy providers because the fluctuations in energy supply and demand can lead to price volatility and grid instability. For this reason, PtG technologies are considered essential to solve this issue to actually offer a system to balance the grid by converting excess renewable energy into storable gases that enhances energy market stability ("Economic Analysis of Power-To-Gas Integration in Renewable Energy Systems", 2022).

When we mention storable gases, we often refer to actions aimed at reducing carbon emissions as a global imperative to combat climate change. This gives another opportunity for the PtG applications to hold the potential to facilitate the decarbonization of sectors such as industry and transportation. The European Commission's "Hydrogen Strategy for a Climate-Neutral Europe" (2020) emphasizes the importance of PtG in achieving carbon reduction targets. By utilizing renewable electricity to produce synthetic fuels, that contributes to lowering carbon emissions.

➢ 2.1 Investment and Market Growth

The PtG market has witnessed substantial investments and growth. Insights from the "Global PtG Market Insights" report (2021) indicate increasing interest and investments in PtG technologies. This growth is driven by the need for innovative solutions to store and utilize surplus renewable energy efficiently.

It's important to note that the economic context for PtG applications varies by region. In Europe, for instance, there is a growing interest in PtG, especially in countries with ambitious renewable energy targets. According to recent data, the European renewable energy market is poised for a 7.6% compound annual growth rate between 2022 and 2026. Additionally, the Power-to-Gas market size in Europe has shown non-negligible growth, reaching 9.5 million euros. However, it's worth noting that this market is fragmented, occupied by several players.

For this reason the PtG market is dynamic and growing rapidly. Recent data shows that the compound annual growth rate (CAGR) of the Power-to-Gas sector is accelerating at a rate of about 10%. This momentum reflects the increasing demand in researching for PtG solutions as an important component of the energy transition.

This makes the PtG solutions attractive specially for industries and sectors that use gas fuels, including mobility, industry, and public administration. The versatility of PtG technologies makes them suitable for a wide range of applications, from producing synthetic methane (CH_4) for industrial processes to providing sustainable fuel for transportation and public services.

This versatility to integrate the PtG systems with storage plays a pivotal role in the efficiency and flexibility of the energy system. PtG storage can be achieved using two primary gases:

H_2 (Hydrogen): Hydrogen can be injected into natural gas (NG) pipelines, enriching the natural gas with up to 6% hydrogen content. Alternatively, it can be stored at high pressure, often around 700 bar, for later use or distribution.

CH_4 (Methane): Synthetic methane (CH_4) produced through PtG is equivalent to natural gas (NG) and can be seamlessly integrated into existing natural gas infrastructure for distribution and consumption.

This synthetic methane can be produced through methanation that is a critical aspect of PtG, facilitating the conversion of hydrogen (H_2) or carbon oxides (CO or CO_2) into synthetic methane (CH_4). Two primary methods are employed for methanation:

Catalytic Methanation: This process involves the use of catalysts to facilitate the chemical reaction between hydrogen and carbon oxides to produce methane.

Biological Methanation: Biological processes, often involving microorganisms, are utilized to convert carbon oxides into methane under controlled conditions.

3. Veolia's Target and Commitment

Considering the mission of Veolia of replenishing resources, where Veolia provides solutions for creating new “secondary” resources that will gradually offset the increasing scarcity of natural “primary” resources, generating new opportunities for social and economic development that protect the environment.

For this reason, Veolia's commitment to sustainability and environmental protection is paramount and allows for specific goals and objectives for PtG projects that take advantage of new energy approaches such as biogas to achieve energy flexibility and independence from natural gas.

➢ 3.1 Biogas Production and Sustainable Energy

Nowadays, Veolia is deeply committed to sustainability, and one of the pivotal aspects of this commitment lies in the research of different sustainable plants to provide a carbon neutral solution for the different business units around the world. One of the configurations that it has been analyzed is production of biogas through innovative processes.

Among the different processes Veolia has long been a pioneer in the anaerobic digestion of organic substrates. This process is not only environmentally responsible but also harnesses the energy potential within waste materials, such as sludge or organic waste. In addition to this, the captured biogas can be subjected to advanced purification techniques, eliminating carbon dioxide (CO_2) and other impurities to produce high-quality biomethane. This biomethane, in its purified form, is a clean and sustainable energy source that can be injected in the gas network. This ensures that renewable energy, in the form of biomethane, becomes seamlessly integrated into existing energy infrastructure.

➢ 3.2 Energy Flexibility and Independence from NG

Veolia's objectives for the future to enhance sustainability, is to research and develop projects within the PtG domain that extend beyond biogas production. Veolia’s vision encompasses broader energy flexibility and a reduced reliance on natural gas.

Veolia envisions a future where energy systems exhibit greater flexibility. This flexibility allows for the efficient storage and distribution of renewable energy, ensuring a stable and resilient energy supply. PtG technologies, such as those explored in this project, play a crucial role in achieving this vision.

Reducing the dependency on natural gas (NG) of the energy plants by increasing the production of synthetic methane (CH_4) through PtG processes. This synthetic methane, chemically equivalent to natural gas, provides an alternative, sustainable energy source. The reduction in NG reliance aligns with Veolia's commitment to reduce greenhouse gas emissions and transitioning to cleaner energy sources.

The main challenge is scaling up the production of synthetic methane (CH_4) through PtG methods. The increased production capacity allows for a more substantial injection of renewable CH_4 into the gas network, contributing to the decarbonization of the energy sector. This process is technically limited by their carbon capture and utilization capabilities along with the Hydrogen production implemented in the PtG system.

4. Market Analysis of Services and Suppliers

The market analysis conducted as part of the IFAISTOS project involved a comprehensive survey of potential Power-to-Gas (PtG) services and providers. Analyzing the existing PtG framework and identifying key providers in the areas of methanation, CO_2 capture, hydrogen (H_2) liquefaction, and CO_2 storage.

➢ 4.1 Design Thinking

The foundation of the market analysis was a carefully designed thinking session intended to gather insights into the PtG landscape. Encompassed various aspects, including technological capabilities, geographic presence, innovation, and sustainability practices. The process includes the business aspects of the application of PtG technologies in Italy, giving as result that technical areas to include in the PtG Market are: electrolysis, methanation, CO_2 capture, hydrogen (H_2) liquefaction, and CO_2 storage.

➢ 4.2 Veolia's Operational Site Scouting Worldwide

To obtain a global perspective on PtG providers and services, an extensive operational site scouting initiative was launched by Veolia to leverage its worldwide presence to identify innovative solutions and projects to get guidance and references, in this case the platform was used to find operational sites that incorporate PtG technologies. This on-ground exploration allowed us to interact directly with PtG practitioners and gain first-hand insights into their operations, especially from the pilots developed by other business units like:

- LE PLESSIS-GASSOT in France that Heat an entire town with biogas
- SHANGHAI in China that turned Shanghai's household waste into a source of green energy
- ÎLE-DE-FRANCE in France that supplies energy to 20,000 households in the Paris region

➢ 4.3 Research and Development: Innovative Ecosystems

Veolia and Siram Veolia have established more than 10 innovative ecosystems across Italy. These ecosystems serve as hubs for research and development activities, fostering collaboration with academic institutions, startups, and industry partners. Leveraging these ecosystems, we engaged in in-depth discussions with experts and innovators in PtG-related fields.

➢ 4.4 Siram Veolia Innovation Library

The Siram Veolia Innovation Library provided a wealth of resources and knowledge related to innovative and disrupting technologies. This library served as a repository of information, research papers, and case studies that informed the market analysis. It facilitated a comprehensive understanding of the state of the art in PtG.

➢ 4.5 Identification of Providers

The core objective of the market analysis was to identify potential PtG service providers and technology innovators. Through a rigorous analysis of survey responses, insights from operational site scouting, engagement with startups, and collaboration within innovative ecosystems, we compiled a list of providers in key PtG domains:

Methanation Providers like Storengy organization with expertise in catalytic and biological methanation processes, analyzing their technological capabilities and market presence.

CO_2 Capture Providers like Airnovation, FuelCell Energy and Techno Project. These are companies specializing in carbon dioxide (CO_2) capture technologies, evaluating their efficiency and applicability within the PtG context.

Hydrogen Liquefaction Providers like Regas, FuelCell Energy and Solid Power are companies offering hydrogen (H_2) production and liquefaction solutions, focusing on their ability to support H_2 storage for PtG applications.

5. Technology Evaluation Methodology

At the core of Power-to-Gas (PtG) initiative lies the selection of appropriate technologies. For this reason it was needed to structure a methodology for evaluating PtG technologies. In order to, take into consideration the dynamic and evolving nature of PtG technologies that encompasses technical, economic, and operational aspects.

➢ 5.1 Technical Evaluation Framework

■ 5.1.1 Technical Meeting

Each provider and services pass through with an in-depth comprehension of the technical principles underpinning each PtG technology. This involves engaging in technical meetings with technology providers and subject matter experts. These meetings are meticulously structured to extract core technical insights, enabling a precise definition of the technology's value within the PtG service context.

■ 5.1.2 Technical Evaluation

After a comprehensive understanding of the technology's principles, we transition to a detailed technical evaluation phase. This phase is characterized by a meticulous assessment of various critical parameters, encompassing:

- ❖ **Technical Functionality and Range of Operation:** A comprehensive analysis of the technology's capabilities and operational scope, including factors such as efficiency, scalability, and adaptability to diverse PtG scenarios.

- ❖ **Technology Complexity:** A thorough evaluation of the complexity involved in implementing and operating the technology. Factors like simplicity and integration ease are of paramount importance in the technology selection process.

- ❖ **Remuneration Method:** A detailed assessment of how the technology generates revenue or value within the PtG service framework, with considerations spanning cost-effectiveness, energy conversion efficiency, and market demand dynamics.

- ❖ **Technological Maturity:** An examination of the technology's maturity level, with a focus on its readiness for seamless deployment within PtG projects. This involves scrutinizing existing installations and relevant case studies.

- ❖ **Criticality of Implementation:** A comprehensive analysis of the technology's criticality in the PtG process chain. Technologies that exert substantial influence on project success and reliability are accorded special attention.

- **Key Performance Indicators (KPIs):** The definition of specific, quantifiable KPIs that facilitate the precise measurement of the technology's performance and its impact on PtG project objectives.

5.1.3 Input & Output Selection

After the technical evaluation, it was necessary to perform a meticulous consideration of the inputs required by the technology and the outputs it generated, in order to model the PtG configuration with the provider or service analyzed. This entails a comprehensive analysis of resource requisites, encompassing energy sources, feedstock considerations, and infrastructure prerequisites, alongside a detailed examination of the resulting products such as synthetic methane (CH_4) or hydrogen (H_2). The compatibility of these inputs and outputs with the project objectives and existing infrastructure constitutes a pivotal factor in the technology selection process.

5.1.4 Modeling

Once the Inputs and Outputs were defined, the technical model can be developed involving the formulation of hypotheses pertaining to technology sizing, drawing upon physical and chemical models, and encompasses the integration of the technology within the broader PtG system. This critical step serves as the cornerstone for assessing the economic viability of the technology and its seamless integration within the PtG ecosystem.

6. Business Model Evaluation

A sustainable Power-to-Gas (PtG) solution requires not just a technical model evaluation but also a business model consideration to determine if the project is feasible and profitable. The Business Model allows us to get an overview of any sustainable Power-to-Gas (PtG) solution. In this chapter, we delve into the intricate web of business models that drive the project. We evaluate these models based on their viability, scalability, and alignment with the economic objectives.

6.1. Outline of Business Models for Each Technology

The first step of the evaluation process involves outlining the business models associated with each PtG technology. This outline encompasses a clear articulation of the value proposition offered by each technology and a detailed breakdown of the cost-revenue structure. This clarity provides a comprehensive vision of the scope of action for each technology within the PtG ecosystem.

6.2 Qualitative Evaluation

Through qualitative assessment, Siram Veolia considers several critical parameters to determine the commercial viability of each technology:

- **Proximity to Siram's Core Business:** We gauge how closely aligned each technology is with Siram's core business. The degree of synergy and integration potential plays a pivotal role in the evaluation.

- **Organizational Complexity:** The organizational intricacy involved in implementing and operating each technology is examined. This factor takes into account resource requirements, skill sets, and operational complexity.

- **Client Subject:** The identification of the potential client base for each technology is critical. We assess the extent to which each technology addresses client needs and market demands.

- **Business Model:** The robustness of the business model associated with each technology is evaluated. This includes considerations of revenue streams, cost structures, and long-term sustainability.

- **Criticality of the Need and Market Trends:** We analyze the criticality of the need that each technology addresses within the market. Additionally, we consider the alignment of each technology with prevailing market trends and future prospects.

➢ 6.3 Capital Budgeting

Capital budgeting is an essential step in the evaluation process. Where Siram Veolia conducts a hypothetical analysis of the cost and revenue structure associated with each technology. This analysis facilitates a quick projection of key financial metrics such as Internal Rate of Return (IRR) and Net Present Value (NPV). These financial indicators provide valuable insights into the economic viability of each technology.

➢ 6.4 Input & Output Selection

The final stage of the business model evaluation process involves the selection of potentially valid services for Veolia based on parameters defined by the business unit for innovative projects such as Total Investment Required (TIR) and Value Added Net (VAN).

7. Model and System Configurations

After the technical evaluation and business model of the different services and providers of PtG systems is possible to explore diverse configurations, process models, and simulation tools that have been instrumental in the analysis. The model incorporates a range of inputs and generates vital outputs that underpin our assessment.

➢ 7.1 Model Inputs

The PtG model is underpinned by a set of inputs that encapsulate the essential parameters for accurate analysis:

- **Overall Boiler Power [kW]:** This parameter represents the power output of the boiler, a critical component in the PtG system.

- **Operating Hours (Winter and Summer) [h]:** Operating hours during different seasons are considered to account for variations in energy demand and production.

- **Photovoltaic System Power [kW]:** The power generated by the photovoltaic system is a key input, representing renewable energy generation.

- **Percentage of CO_2 for Methanation [%]:** The percentage of carbon dioxide used for methanation is crucial for synthetic methane production.

- **Storage Type [H_2, Electric]:** The choice of storage type, either hydrogen (H_2) or electric, has significant implications for system operation.

- **Storage Size [H_2, Electric]:** The size of the storage, whether H_2 or electric, influences the system's capacity and flexibility.

- **Initial Storage Load Percentage [%]:** This parameter represents the initial load condition of the storage system.

7.2 Configurations

The analysis encompasses two distinct PtG system configurations, each with its unique characteristics:

7.2.1 Power to Gas with H_2 Storage

This configuration involves the conversion of renewable electricity to hydrogen through electrolysis. The generated hydrogen is stored and later used for methanation to produce synthetic methane, from the CO_2 capture from the boiler. The system relies on hydrogen storage to manage energy fluctuations. As shown in fig 1.

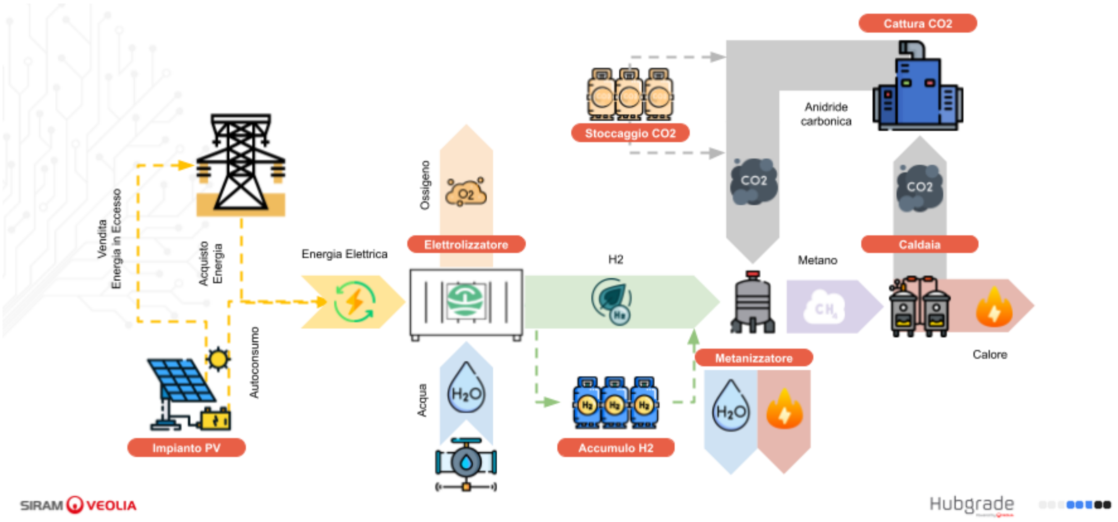

Fig 1. Power to Gas with H_2 Storage configuration

■ 7.2.2 Power to Gas with Electric Storage

This configuration involves the conversion of renewable electricity to hydrogen through electrolysis. The generated hydrogen is used for methanation to produce synthetic methane, from the CO_2 capture from the boiler. In this configuration, excess electricity is stored directly in an electric storage system. This electricity can be retrieved when needed to support methanation or other energy-demanding processes. It offers a flexible approach to energy storage. As shown in fig 2.

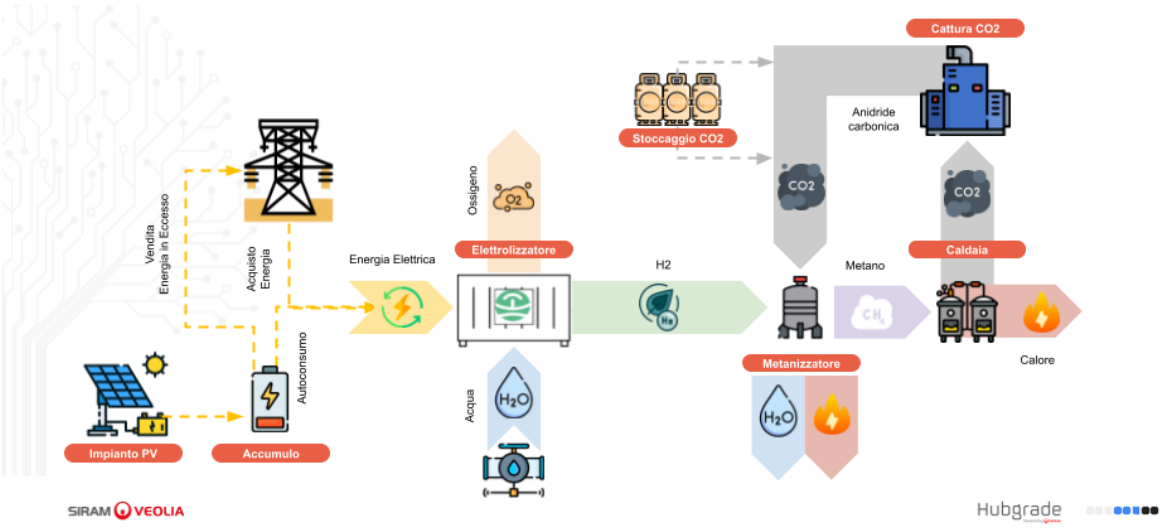

Fig 2. Power to Gas with Electric Storage configuration

➢ 7.3 Model Logic

Internally, the model undergoes a dynamic process to determine various parameters based on the defined inputs. The sequence of calculations within the model unfolds as follows:

- Boiler Size and CH_4 Quantity: The model calculates the quantity of CH_4 required to guarantee the kW power output during the defined working hours, based on the size of the boiler.

- Sabatier Reaction: Using the determined quantity of moles of CH_4, the model employs the Sabatier reaction to calculate the number of moles of hydrogen (H_2) needed to facilitate the process.

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_20$$

- Electrolyzer Size and Production: With the number of moles of H_2 calculated, the model determines the required outflow of the electrolyzer to guarantee the desired production of CH_4.

- ❖ Renewable Resource Size: Once the size of the electrolyzer is defined, the size of the renewable plant is defined as input, then the model estimates as output the hourly power supplied by the renewable plant to fully or partially supply the energy required by the electrolyzer.

- ❖ Storage Type Selection: In this phase, the type of storage is determined based on the model's calculations. This choice can be either at the energy production stage with electric storage or at the energy utilization stage as hydrogen storage.

These internal processes ensure that the PtG system is configured optimally to meet the defined objectives, considering factors such as energy production, storage, and resource utilization.

➢ 7.3 Model Output

The PtG model generates several key outputs critical for our assessment:

- ❖ **Annual Electrical Consumption [MWh]:** This output quantifies the total electric consumption of the system over the course of a year.

- ❖ **Energy Used from the Grid [MWh]:** This metric delineates the amount of energy drawn from the grid to meet system demands.

- ❖ **Capex [€]:** The capital expenditure, representing the financial investment required for implementing the PtG system.

- ❖ **Opex [€]:** Operating expenses, encompassing costs incurred in the day-to-day operation of the PtG system.

- ❖ **Revenues [€]:** This output reflects the financial gains or income generated by the PtG system, including income from energy sales or other revenue streams.

- ❖ **Time System Simulation:** The hourly energy fluxes of the system simulation, over which the PtG system's performance and financial metrics are assessed.

8. Conclusions

The IFAISTOS project embarks on an exploratory research into the ever-evolving landscape of modern energy technologies and solutions, with a resolute objective of achieving a sustainable "Power-to-Gas" (PtG) transformation. At its core, the project seeks to leverage the power of renewables, from various resources like solar, wind, biogas, hydrogen, and different storage solutions, along with CO_2 capture, to craft an innovative technical configuration capable of generating synthetic methane while fostering environmental stewardship.

In the modern energy landscape, the IFAISTOS project represents an attempt at innovation, committed to harnessing the full potential of emerging technologies. Our mission is to select the most suitable technical configuration to align with the goals of our PtG.

The project's commitment to mitigating climate change is evident through CO_2 capture. The aim is to divert carbon dioxide emissions from industrial processes and power generation, turning them into valuable resources. Exploring opportunities in the food sector, by capitalizing on the demand for liquified CO_2, further promotes circular economy principles and sustainability.

At the core of the PtG system lies the electrolysis process, converting renewable energy into hydrogen. A meticulous analysis selects the most suitable adaptation of this process, vital for the simulation of a model capable of technically analyzing the generation costs and benefits of PtG solutions.

Internally, the model dynamically determines various parameters based on the defined inputs, ensuring that the PtG system is configured optimally to meet the defined objectives, considering factors such as energy production, storage, and resource utilization.

The PtG model offers a comprehensive evaluation of three distinct configurations: Power to Gas with H_2 storage, Power to Gas with Electric Storage, and Hydrogen & Natural Gas Mix. These configurations generate vital outputs, including Opex, Revenues, and the Time System Simulation, forming the basis of our assessment.

In conclusion, the IFAISTOS project represents a comprehensive endeavor to unlock the potential of PtG solutions in a rapidly evolving energy landscape. It underscores the critical role of renewables, energy storage, and CO_2 capture in creating sustainable, resilient, and environmentally responsible energy systems. The pages of this paper revealed the structure of the analysis, shedding light on the many facets of the PtG solution, its technical difficulties and its potential to redefine the energy paradigm.

The IFAISTOS project envisions a future where PtG solutions play a pivotal role in the transition to a sustainable, reliable, and resilient energy ecosystem. Our commitment to sustainability and innovation drives our exploration of PtG technologies, with the ultimate goal of delivering solutions that harmonize with the environment, benefit society, and enhance economic prosperity.

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