TH2ICINO

D2.6 TH2ICINO PLANIFICATION AND KPIS DEFINITION (FINAL VERSION)

V1.1

TECHNICAL REFERENCES

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INTRODUCTION

GENERAL OBJECTIVE

The main goal of the document is to represent and create a solid foundation for the creative conceptualization and organization of the Hydrogen Valley. This framework is designed to support a sustainable and interconnected hydrogen economy, utilizing sustainable energy sources to produce green hydrogen. The deliverable focuses on outlining the sizing and organization of five key pillars: green energy production, hydrogen production, hydrogen storage, hydrogen distribution, and hydrogen usage. By identifying the necessary technical and operational criteria for each pillar, this document will act as a strategic roadmap for implementing and expanding hydrogen technologies. In addition, the project is designed to support the goals outlined in the Clean Hydrogen Joint Undertaking Strategic Research and Innovation Agenda for 2021-2027, which will help advance efforts to reduce carbon emissions in the region and improve transportation infrastructure in the valley. This milestone will lay the foundation for future research and planning stages, guaranteeing that the Hydrogen Valley becomes a crucial factor in facilitating the shift to cleaner energy sources and promoting economic sustainability in the area.

FIGURE 1: RECREATION OF A HYDROGEN VALLEY

BACKGROUND

The use of hydrogen as a primary source of energy for transportation is a major step towards reducing global carbon emissions. Hydrogen is efficient and clean, making it a great alternative to traditional fossil fuels for different modes of transport. There has been notable progress in creating hydrogen-powered vehicles like cars, buses, trucks, trains, and ships. This progress is supported by advances in fuel cell technology, which efficiently convert hydrogen into electricity, powering vehicles with water vapor as the only emission.

Moreover, the move towards hydrogen in the mobility industry has been bolstered by improvements in infrastructure for hydrogen production, storage, and distribution. Global initiatives for large-scale green hydrogen production, powered by renewable sources like wind and solar energy, are underway. These projects play a critical role in promoting sustainable hydrogen production and highlighting the environmental advantages of using hydrogen for transportation.

Nevertheless, incorporating hydrogen into the transportation industry comes with its fair share of obstacles. Issues such as cost-effectiveness, building the necessary infrastructure, and gaining public approval all stand in the way. The high price of hydrogen fuel cells and the initial cost of setting up hydrogen facilities present major hurdles for its widespread use. Additionally, ensuring the efficiency of hydrogen production and streamlining its distribution and storage processes call for continuous advancements in technology and operations.

Although facing obstacles, the use of hydrogen in transportation is steadily growing with support from policies, advancements in technology, and a greater awareness of the importance of sustainable transport. Governments and industries are investing significantly in research, development, and expanding hydrogen refueling infrastructure to promote hydrogen strategies.

The history of using hydrogen in transportation provides a strong foundation for establishing the Hydrogen Valley. Building on these advancements, the initiative strives to improve the expandability of hydrogen technologies and boost the economic and environmental well-being of the area.

FIGURE 2: LOCATION OF TH2ICINO HYDROGEN VALLEY

CHALLENGES AND POTENTIAL

Creating a hydrogen hub focused on mobility vehicles at Malpensa Airport poses various challenges and opportunities for transitioning to sustainable energy. A key hurdle is setting up a robust hydrogen infrastructure to meet the airport's fleet and valley industries' energy requirements. This involves building production plants, storage systems, and distribution channels to supply hydrogen to airports and industries efficiently.

In addition, incorporating hydrogen-fueled transportation options at Malpensa Airport involves working closely with various parties like airport officials, transport companies, energy suppliers, and regulatory agencies. It is crucial to smoothly integrate these solutions with current facilities and operations, all while adhering to strict safety and regulatory requirements, which presents a significant hurdle.

Furthermore, broadening the reach of the hydrogen hub to provide hydrogen to customers in the local industrial sector brings about more challenges. Big businesses with high energy usage have distinct needs and practical factors that need to be handled in order to help them shift to hydrogen-powered solutions. This could mean tailoring hydrogen supply networks to suit particular demand patterns, improving the efficiency of production and distribution logistics, and conquering financial obstacles linked to initial investments in hydrogen infrastructure.

In spite of the hurdles, creating a hydrogen valley at Malpensa Airport has huge potential for promoting sustainable growth and economic progress. By utilizing hydrogen as a clean energy source, the area can lower its carbon emissions, improve energy reliability, and encourage advancements in different industries. Moreover, setting up a hydrogen ecosystem can open up new business prospects, draw in investments, and establish the region as a frontrunner in sustainable technology and infrastructure advancement.

In order to unlock this potential, we need to take proactive measures to tackle the technical, regulatory, and financial obstacles that come with planning a hydrogen valley. This could mean building partnerships between public and private parties, finding ways to fund infrastructure projects, and creating policies that encourage the use of hydrogen technologies.

LEGISLATION

The European Commission has elaborated the COMMISSION DELEGATED REGULATION (EU) 2023/1184 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin, that affects to green hydrogen production being compulsory to be aligned with said regulation in order to ensure the green hydrogen category.

Recognizes that RFNBOs can be produced from electricity from direct connection or from electricity from the grid. In the latter case, it is established:

A. General rule: renewable hydrogen will be counted as fully renewable when the requirements of additionality are met (if the renewable installation entered into operation no more than 36 months before the electrolyzer), temporal correlation (until 12/31/2029 monthly correlation is required; from 1/1/2030 hourly correlation) and geographical correlation (based on the location of the renewable installation).
B. 3 Exceptions:
    a. If the electrolyzer is located in a supply area where the average proportion of renewable electricity exceeded 90% of the electricity mix in the previous calendar year and the production of RFNBO does not exceed the maximum number of hours established in relation to the proportion of renewable electricity in the supply area, the hydrogen will be considered renewable without having to meet additionality, temporal or geographical correlation.
    b. When the 90% case is not met, RFNBO producers may count grid electricity as renewable if the intensity of greenhouse gas emissions from the electricity grid in the supply area where the electrolyzer is located is less than 18 gCO2eq/MJ, subject to certain assumptions.
    c. Grid electricity for RFNBO production may also be counted as renewable if the electricity is consumed during a deviation settlement period during which the RFNBO producer must demonstrate that the renewable installation has been dispatched downwards or that the electricity consumed for RFNBO production reduced the need for dispatch in an equivalent amount.

COMMISSION DELEGATED REGULATION (EU) 2023/1185 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a minimum threshold for greenhouse gas emissions savings of recycled carbon fuels and by specifying a methodology for assessing greenhouse gas emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels establishes how GHG emissions are computed, being a determining factor in conditioning the assumptions under which produced hydrogen will be counted as renewable (provided that a monthly PPA is available and temporal and geographical correlation is met).

RELATIONS WITH OTHER TASKS

The Task 2.1: Hydrogen Valley Innovative Conceptual Design and Planning is intricately connected with the various tasks within Work Package 2 (WP2), each contributing to the holistic development and implementation of the Hydrogen Valley project. Furthermore, Task 2.1 also intersects with other work packages of the project sharing information or data as input or outputs regarding the specific activity. Work Package 3 (WP3) – Master Planning Tool (MPT), and activities within WP4 – Off-takers' Evolution, reflecting the integrated nature of the project and its broader implications for stakeholders and the region.

TABLE 1: RELATED INTERDEPENDENCES IN WP2

Task	Description
T2.2	Task 2.1 collaborates closely with Task 2.2: Hydrogen Valley Infrastructure Implementation, encompassing Subtasks 2.2.1: Hydrogen Valley Detailed Design and Engineering, and 2.2.2: Hydrogen Valley Assets Installation. The conceptual design and planning outputs from Task 2.1 provide critical inputs for the detailed engineering and installation phases of the hydrogen infrastructure, ensuring alignment with the overarching vision and objectives of the Hydrogen Valley project.
T2.3	Task 2.1 intersects with Task 2.3: Hydrogen Valley Logistic Chain, as both tasks focus on optimizing the logistical aspects of hydrogen production, distribution, and consumption within the valley. The conceptual design and planning efforts lay the groundwork for defining efficient logistics strategies, which are further refined and implemented in Task 2.3 to ensure seamless operations within the Hydrogen Valley ecosystem.
T2.4	Hydrogen Valley Ecosystem Operation and Value Chain Optimization builds upon the conceptual framework established in Task 2.1 to optimize the operational efficiency and economic viability of the Hydrogen Valley ecosystem. By leveraging the insights generated from Task 2.1, Task 2.4 refines operational models and identifies value-added services, thereby maximizing the socio-economic benefits of the project.
T2.5	Hydrogen Valley Performance and Expansion relies on Task 2.1 to define key performance indicators (KPIs) and performance monitoring methodologies, essential for assessing the effectiveness and sustainability of the Hydrogen Valley concept. Task 2.5 systematically tracks progress and guides strategic expansion initiatives, leveraging the insights provided by Task 2.1.

TABLE 2: RELATED INTERDEPENDENCIES IN TH2ICINO PROJECT

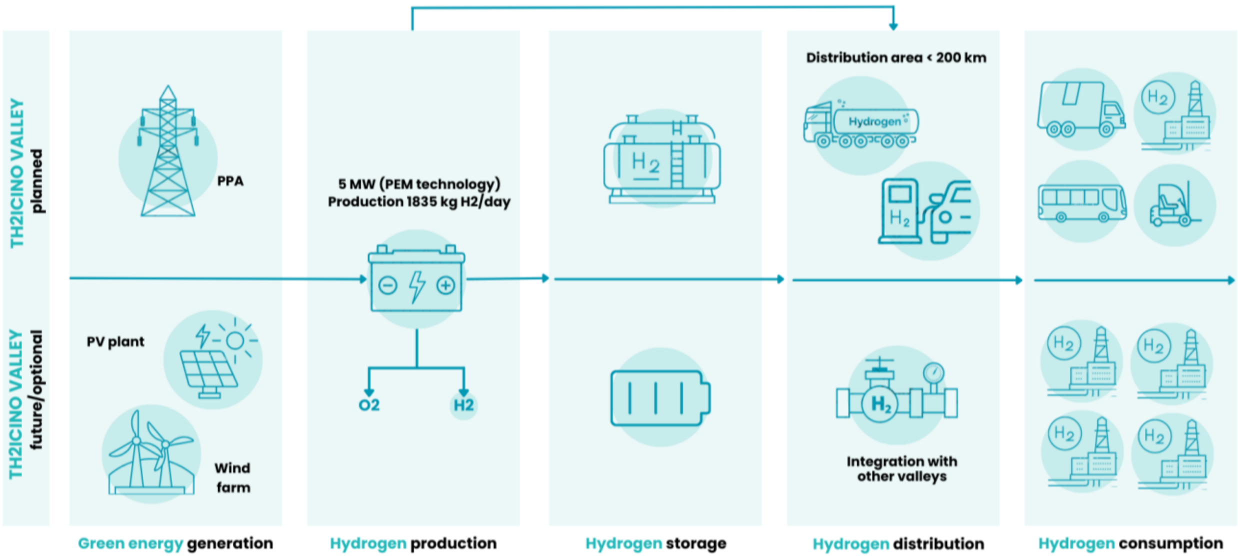
WP	Description
WP3	Task 2.1 relates to WP3 – Master Planning Tool (MPT), which aims to equip stakeholders with a tool to assess the value of new activities and integrate into the Hydrogen Valley ecosystem effectively. The outputs of Task 2.1 feed into WP3, particularly in designing the baseline system within the Master Planning Tool, which helps study the activities of new stakeholders in relation to this baseline.
WP4	Task 2.1 also intersects with activities within WP4 – Off-takers' Evolution, as it provides crucial data on identified consumers and their consumption patterns. This data informs the development of production planning systems versus consumption, facilitating efficient resource allocation and meeting demand effectively within the Hydrogen Valley ecosystem. The interconnectedness of Task 2.1 with other tasks within WP2, WP3, and WP4 underscores the collaborative and integrated approach taken in the development and operation of the Hydrogen Valley project.

METHODOLOGY

CONCEPTUAL DEVELOPMENT

The next figure shows the conceptual development of TH2ICINO hydrogen valley. Two zones can be distinguished, the current one, which is designed for mobility and local industry, and the future one, which will be expanded considering interconnections and additional green energy generation of electricity.

FIGURE 3: CONCEPTUAL DEVELOPMENT OF THE CURRENT AND FUTURE TH2ICINO



In the future it is intended to expand this hydrogen valley in such a way that new uses for hydrogen can be implemented, including the installation of a photovoltaic plant in Malpensa. Additionally, plans include the storage of hydrogen with batteries and the connection of the valley with other hydrogen valleys.

HYDROGEN VALLEY CONCEPTION

GREEN ENERGY GENERATION

The TH2ICINO project is an implementation aimed at setting up a Hydrogen Valley with green energy at the foundation of its electricity generation system. At the heart of the idea is a hydrogen production facility that utilizes an electrolyzer powered by electricity. In order, therefore, for this facility's operations to follow sustainable practices it will source all the power it needs from the grid using Power Purchase Agreement (PPA).

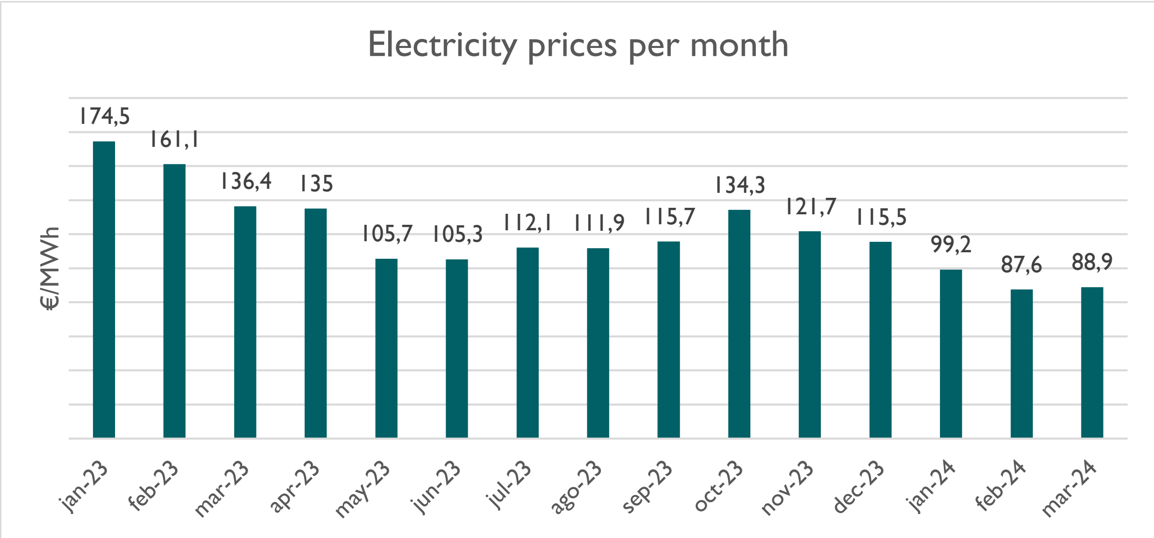
A PPA is an agreement to buy and sell clean energy on a long-term basis from a specific asset at a fixed price, meeting the requirements set out in the Delegated Acts in terms of time correlation to produce RFNBOs. By doing this, agreement will secure a supply of electricity coming solely from clean renewable sources for it.

The TH2ICINO project has studied historical electricity prices in the Italian electricity market and PPA market trends have been thoroughly evaluated to establish realistic values for a precise economic assessment of the hydrogen production's viability. This detailed pricing framework is crucial for effective financial allocation and forecasting future operational budget, enabling precise planning. In addition, it has been studied that the PPAs prices in Europe has fallen by 12.8 % in January 2024, which can also give us a clue to predict prices in the future.

Electricity prices in Italy work with the PUN (single national price, by their italian acronym). The PUN is the wholesale reference price of electricity that is developed on the Italian Electricity Exchange market, where sales between producers and suppliers are regulated; it is a national weighted average of hourly and daily electricity sales prices.

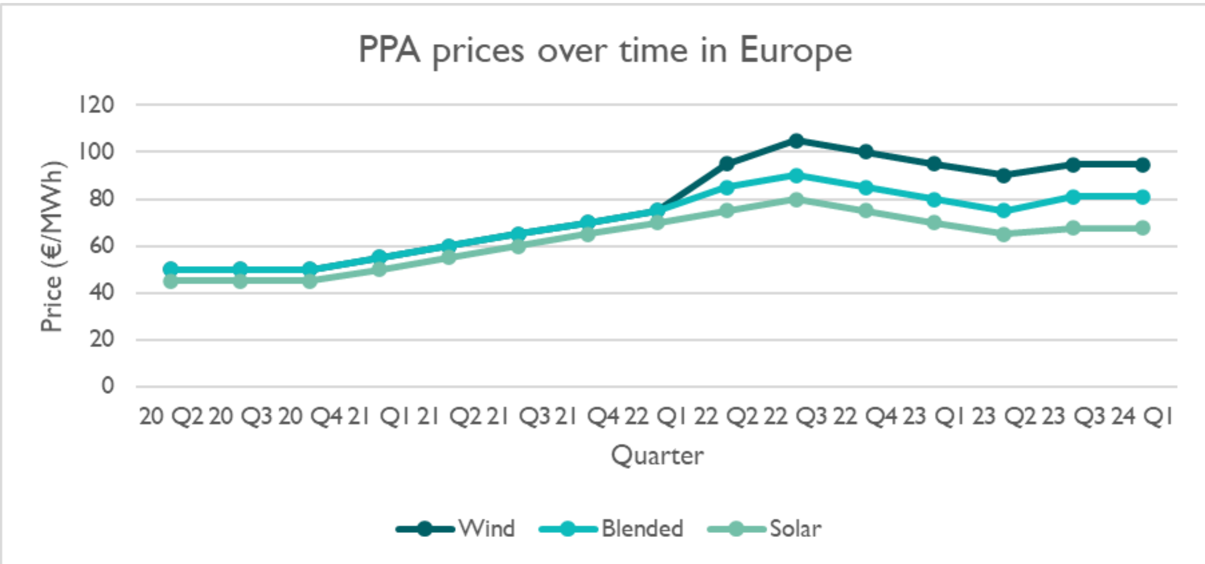
The figure shows the monthly electricity price, which are going to be the estimated PPA prices:

FIGURE 4: ELECTRICITY PRICES PER MONTH = PPA PRICES



With this data and the next figure showing the PPA prices per month depending on whether it is solar, wind o mixed energy, we will choose an approximate price.

FIGURE 5: PPA PRICES OVER TIME IN EUROPE



The rate is going to be bi-hourly, there are two types of time slots where the price of electricity is different, these time slots are:

- Peak hours: any time between 8 am and 7 pm from Monday to Friday, except national holidays.
- Off-peak hours: all hours between 7 pm and 8 am from Monday to Friday, weekends and national holidays.

With the PPA prices studied, an estimate of the electricity price per month and time slots is provided, according to Table 3.

TABLE 3: ELECTRICITY PRICES

Month	Peak hours (8 am – 7 pm) (€/MWh)	Off peak hours (7 pm- 8 am) (€/MWh)
January	174,5	87,25
February	161,1	80,55
March	136,4	68,2
April	135	67,5
May	105,7	52,85
June	105,3	52,65
July	112,1	56,05
August	111,9	55,95
September	115,7	57,85
October	134,3	67,15
November	121,7	60,85
December	115,5	57,75

In the future, Malpensa Airport is planning to improve its capacity as producer of clean energy by expanding onto a 15 MW solar photovoltaic (PV) plant located near the airport. This is believed to make it possible for the hydrogen production facility to operate smoothly while at the same time boosting the general energy grid within Hydrogen Valley. With solar PV plant being introduced, the degree of flexibility will go up on the side of energy supply as well help cut down costs associated with electricity consumption hence it is a win-win situation. This serves as an indication of the endeavor towards ecological balance that this undertaking has undertaken since it is geared towards promotion green technology.

PPA CONTRACTS IN THE ENERGY SECTOR

PPAs can be defined as long-term renewable energy purchase agreements between a producer (seller) and a buyer (utilities/corporates). Due to price volatility in the electricity market, these contracts allow companies to secure fixed prices, thereby fully or partially reducing the economic risks that such volatility may pose. The main types of PPAs are:

- Physical PPA: the buyer receives the electricity at its site (through the grid or a direct wire), and the supplier ensures that the renewable energy output is transmitted through the grid to the offtaker's meter.
- Virtual PPA (vPPA) / Contract for Difference (CfD): It is a financial agreement. The offtaker buys electricity on the market as usual but settles the difference between market price and PPA strike price with the renewable producer.

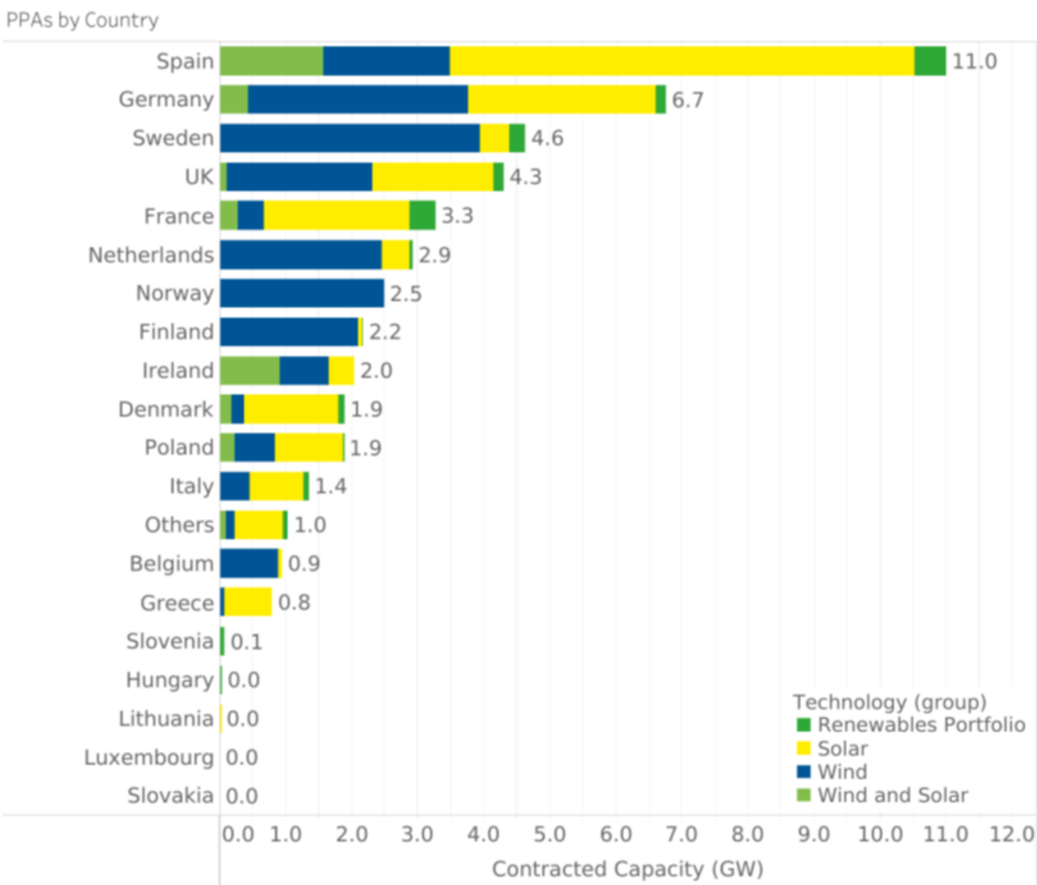
Hydrogen production requires the implementation of capital-intensive projects. In general terms the electrolyzers are the highest capital cost component of the project and require a large amount of energy to operate. A long-term Power Purchase Agreement (PPA) considering a range between 10–20 years or plus, can ensure the best profitability of the project as they:

- guaranteeing electricity volume (either hourly or baseload supply),
- stabilizing prices by hedging against market volatility,
- providing certificates that prove the renewable origin of the electricity (e.g., Guarantees of Origin or hourly certificates),

- ensuring compliance with EU RFNBO regulations regarding additionality, temporal correlation, and geographic correlation — all of which are necessary for hydrogen to be considered “renewable” under EU law.

The Power Purchase Agreement (PPA) market in Europe has experienced significant growth in recent years, showing a marked increase in the number of contracts signed compared to global trends. Among renewable technologies, photovoltaic (solar PV) projects have been the most widely adopted within PPA frameworks, thanks to their decreasing levelized cost of electricity (LCOE), scalability, and rapid deployment capabilities. The following figures provide a visual overview of key trends shaping the PPA landscape in Europe.

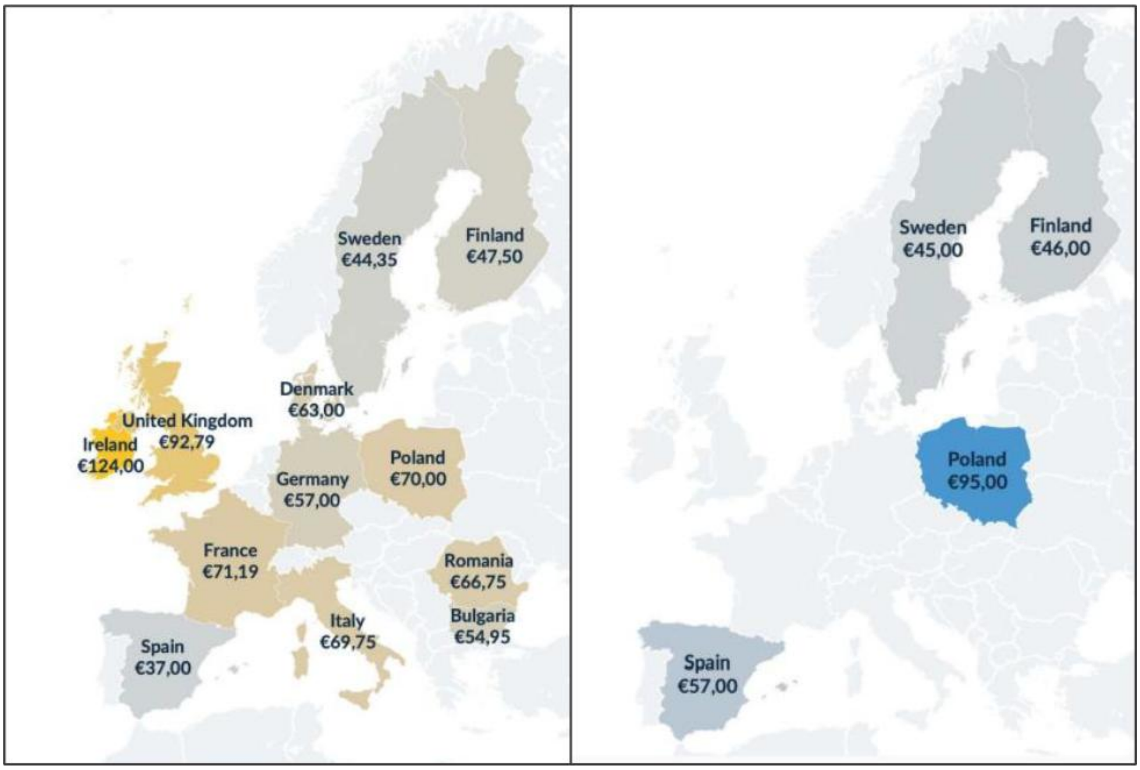
FIGURE 6: PPAS BY COUNTRY AND CONTRACTED CAPACITY (GW) IN 2024. (SOURCE: RE-SOURCE)



The chart highlight the PPA contract volumes, the impact of photovoltaic technology in new agreements, and the geographical distribution of installed capacity across EU member states.

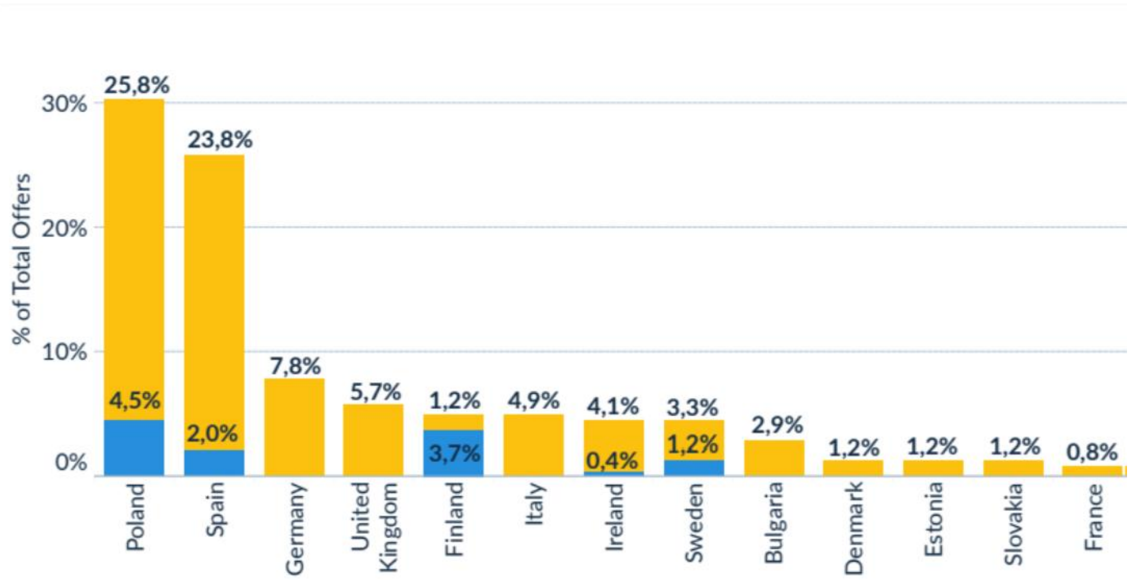
For the current year (2025), based on data collected during the first quarter (Q1), the following figures present the observed PPA prices obtained from market databases. The analysis highlights a notable scarcity of wind PPAs in contrast with an abundance of solar PPAs, reflecting ongoing market preferences and project availability across Europe.

FIGURE 7: PPA CONTRACT PRICES IN DIFFERENT EUROPEAN COUNTRIES BY TECHNOLOGY: PHOTOVOLTAIC (LEFT) AND WIND (RIGHT). (SOURCE: LEVELTEN Q12025 REPORT)



Spain plays a significant role in Europe's market price competitiveness for both wind and solar technologies. Focusing on Italy, PPA prices are positioned around the European average, at €69.75/MWh.

FIGURE 8: TOTAL PPA OFFERS RATE BY COUNTRY. (SOURCE: LEVELTEN Q12025 REPORT)



During Q1 of 2025, PPA offers in Poland and Spain stood out, accounting for 50% of the total market share in Europe. Following them, a group of countries — including Italy — each represented a similar share of around 5% of the total PPA offer across the region.

HYDROGEN PRODUCTION

OVERVIEW OF THE ELECTROLYZER: THE PLUG EX-2125D

As part of the TH2ICINO project, the electrolyzer selected for hydrogen production is the Plug EX-2125D, supplied by the company Plug. This electrolyzer is a best-in-class Proton Exchange Membrane (PEM) system, designed for high performance and reliability based on nearly 50 years of field experience. Key specifications and features of the Plug EX-2125D include:

- **Hydrogen production capacity:** The EX-2125D can produce up to 2,125 kg of hydrogen per day, with a production rate of 1,000 Nm^3 per hour.
- **Efficiency:** The system exhibits an average stack efficiency of 49.9 kWh per kg of hydrogen produced.
- **Purity and pressure:** It delivers hydrogen at a purity of up to 99.999% and a pressure of 40 barg (580 psig) without the need for an external compressor.
- **Water Consumption:** The electrolyzer consumes approximately 13 liters of water for every kilogram of hydrogen produced.
- **Operational flexibility:** The EX-2125D is designed for instantaneous load following, making it suitable for integration with grid or renewable energy sources. It has a start-up time of 30 seconds when warm and less than 5 minutes when cold.
- **Physical and environmental parameters:** The installed footprint is 87.9 m^2, and it operates effectively within an ambient temperature range of -20°C to +40°C.
- **Compliance and certifications:** The system is compliant with ISO 22734, NFPA 2, and CE standards.

TABLE 4: EX-2125D SYSTEM SPECIFICATIONS

Input	
Stack Power Consumption	Up to 5MW
Voltage & Frequency	4.1 to 34.5kVAC 60HZ (USA) 11 to 33kVAC 50HZ (EU)
Water Consumption	13 liters per kg of H2 produced
Output (Hydrogen Gas)	
Volume	1,000 Nm^3 / hour
Mass	2,125 kg / day
Purity	Up to 99.999%
Pressure	40 barg / 580 psig (w/o compressor)
Operational	
Start Up Time	30 sec warm / < 5 min cold
Average Stack Efficiency	49.9 kWh / kg
Load Following	Instantaneous
Physical / Environment	
Installed Footprint	87.9 m^2 / 960 ft^2
Ambient Temperature	-20°C to +40°C (wider temperature range optional)
Other	
Compliance / Certifications	ISO 22734, NFPA 2, CE
Specific consumption	52 kWh / kg
Cell degradation rate	1,1 % / year
Useful life	10 years (cell replacement) / 30 years (electrolyzer)
Minimum possible charge for the electrolyzer	30 %

AUXILIARY EQUIPMENT REQUIRED

The installation of the Plug EX-2125D electrolyzer is supported by several auxiliary components to ensure efficient and safe hydrogen production. According to LHYFE, the essential auxiliary equipment for a 5MW hydrogen plant includes:

- **Water treatment Systems:** Essential for ensuring the quality of water fed into the electrolyzer.
- **Hydrogen purification systems:** Responsible for refining the produced hydrogen to reach the high purity levels demanded by end-use applications or regulatory standards.
- **Hydrogen gas compression:** Provides the necessary pressure levels for storage, transport, or downstream use of hydrogen, depending on the system design and application.
- **Electrical facilities:** Deliver the necessary electrical infrastructure to power the electrolyzer and auxiliary systems, ensuring stable and efficient energy distribution.
- **Utilities Process Facilities:** Supporting the general operation of the plant.
- **Storage & export facilities:** For the safe storage and transportation of produced hydrogen.
- **Hydrogen gas export and metering:** To manage and measure the flow of hydrogen leaving the production facility.
- **Safety system:** Critical for ensuring the operational safety of the plant.
- **Instrumentation & automation:** Allow for precise monitoring and real-time control of operational parameters, contributing to process optimization and system reliability.
- **Control system:** To manage the overall operation of the plant.
- **Piping:** For the transportation of hydrogen within the plant.
- **External Connections:** For integrating the plant with external systems and utilities.

AVAILABLE ECONOMIC DATA (CAPEX & OPEX)

The economic feasibility of the hydrogen production installation is characterized by both capital and operational expenditures.

The **Capital Expenditure (CAPEX)** encompasses the **Total Installed Cost (TIC)**, which is determined based on the installed electrolyzer capacity and supporting systems.

The **Operational Expenditure (OPEX)** involves several key components:

- **Fixed Operating Costs:** Include elements such as land use, personnel, and scheduled maintenance activities.
- **Water consumption:** The plant expected to consume 30 m^3 of water per day, the cost of which depends on the water source.
- **Electrical efficiency:** The system is designed to operate at an energy consumption rate of approximately 59 kWh per kilogram of hydrogen produced, subject to the operation plan.
- **Plant operating hours:** The electrolysis plant projected to operate for 6,570 hours per year out of a possible 8,760 hours.

HYDROGEN STORAGE

The hydrogen storage pillar is a critical component, ensuring that hydrogen produced from green energy sources is safely and efficiently stored for subsequent distribution and use. This section outlines the current plans and considerations for hydrogen storage within the project, incorporating input from project partner LHYFE and exploring potential storage alternatives.

LHYFE"S CONTRIBUTIONS

LHYFE has provided preliminary data on the CAPEX and technical requirements for hydrogen storage. The key points from their contribution are as follows:

- **Hydrogen tanks:** The comparative CAPEX for hydrogen tanks varies depending on storage volume and pressure requirements. A nearby Hydrogen Refueling Station (HRS), associated with the EDISON project, is available in the vicinity. The TH2ICINO project includes an HTFFS (High-Temperature Fast Fill System) area and dedicated containers for filling mobile hydrogen tanks, which will be transported by truck.
- **Compressor requirements:** The CAPEX varies depending on the pressure requirements.
- **Electric batteries:** Currently, no electric batteries are included in the CAPEX and operational plan for hydrogen storage.

ON-SITE BUFFER STORAGE

A viable and practical option for hydrogen storage is the implementation of **buffer storage directly at the electrolysis plant**. This approach involves maintaining a small reserve of hydrogen to manage production fluctuations and ensure a steady supply. Buffer storage helps mitigate the variability in hydrogen demand and supply, providing operational flexibility. Typically, buffer storage systems use pressurized tanks that can hold hydrogen at varying pressures, depending on the storage capacity required.

Buffer storage offers several advantages. Firstly, it ensures the **immediate availability** of hydrogen, allowing it to meet sudden demand spikes or compensate for production shortfalls effectively. Secondly, it provides **flexibility**, enabling smooth operation of the electrolysis plant by accommodating fluctuations in hydrogen production and consumption. Lastly, buffer storage enhances **efficiency** by reducing the need for constant production adjustments, thereby improving the overall efficiency of the system.

ALTERNATIVE STORAGE SOLUTIONS

In future updates, we will address the possibility of storing energy at the hydrogen production plant in the form of electricity generated by a potential photovoltaic plant, using electric batteries or alternative storage systems. However, it is important to note that one of the main disadvantages of this method is the efficiency problems during charging and discharging processes. These issues can result in significant energy losses, affecting the feasibility and effectiveness of electric battery storage. Additionally, the produced hydrogen will be evaluated for storage in tanks at various pressures or directly in transport tankers.

HYDROGEN DISTRIBUTION

All hydrogen is distributed through LHYFE trucks equipped with different compartmentalized hydrogen cylinders. These trucks are designed to safely transport hydrogen under specific pressure and volume conditions, ensuring the integrity and efficiency of the delivery process. The hydrogen cylinders are typically maintained at high pressure, ranging from 350 to 700 bar, depending on the volume and transportation requirements. Additionally, the installation of a hydrogen refueling station (originating from another project) is anticipated at the facility, enhancing our distribution capabilities. Detailed information regarding transportation routes, consumption, and costs will be provided in the specific task 2.3.

HYDROGEN CONSUMPTION

- 500 Tons/year of green H_2 produced within the end of the project.
- Another 1,500 tons/year of green H_2 (from PV) to be produced thanks to the synergy in Cairate and thanks to the NEXT Generation EU Recovery and Resilience Funds (RFF).
- Up to 4400 tons CO_2/year saved thanks to the initial production (500tons/year of H2). CO_2. Savings are calculated considering the average emissions of 200 kg/MWh of methane and 250kg/MWh from Diesel engines combustion. At least 7 long-range buses and 35 trucks will be identified for a future replacement or retrofitting after the project ends, according to the results (technical, financial) from those (at least 3) retrofitted within the project.

As shown in Figure 2, the current plant for the TH2ICINO hydrogen valley is the use of hydrogen for airport mobility vehicles.

The Project foresees in terms of airport mobility vehicles:

- At least 3 different types of vehicles will be retrofitted.
- At least 20 special vehicles (e.g. Special vehicles in Malpensa airport), identified to be retrofitted or replaced after the project end.

On the other hand, to complete the consumption of hydrogen produced, it is proposed to use the remaining hydrogen for use in industry, for example (steel industries) located within a radius of less than 200 km.

The consumption found from public information sources (companies' sustainability reports) is as follows (Table 5):

TABLE 5: POTENTIALLY OFFTAKERS

Company	Distance to Malpensa (km)	Energy consumption (MWh/year)	NG consumption (MWh/year)	Information
Secondo Mona	10	4.291,51	2.518,45	Secondo Mona - Sustainability report
Tenaris – Dalmine SPA	90	4.023.000	7.148,92	Tenaris - Sustainability report
Fonderia di Torbole	130	36.680,34	-	Fonderia di Torbole - Sustainability report
ORI Martin	137	429.522,24	203.999,89	ORIMartin - Sustainability report
Lucchini	140	204.422,79	244.831,25	Lucchini - Sustainability report

Formal Expressions of Interest to be involved in the future development will be collected from at least: 5 stakeholders from the production/distribution part of the value chain, 25 potential off-takers, from transportation, energy and industry sectors, 3 academic bodies, 5 public authorities.

INFORMATION GATHERING

A summary table is presented below, compiling the data provided by the project and its partners for integration into the analysis tool.

TABLE 6: SUMMARY TABLE OF DATA GATHERING

	Who	Data
Green energy generation	RINA-C	Electricity prices in Italian market
Economic values of hydrogen feasitiy	LHYFE	CAPEX/OPEX electrolyzer Additional Equipment Installations
Mobility vehicules	EMISIA	Type of vehicules Consumption data Operation data

KPIS DEFINITION

One of the aims of the first steps of the hydrogen valley planification is to identify representative KPIs of TH2ICINO hydrogen facility. Some KPIs proposed in the Annexes of the Clean Hydrogen JU SRIA are taken into consideration but preliminary to compared proposed scenarios in the project, in the mid-term edition are considered:

FIGURE 9: KPIS DEFINITION

- LCOH: The Levelized Cost of Hydrogen represents the calculation of hydrogen production costs.
- H_2 stored rate: It measures during the operation year the stored hydrogen in the tank buffer.
- Electrolyzer operation rate: It measures production hours and production quantity (H_2 kg).

DEFINITION OF ASSUMPTIONS, CONSTRAINTS AND BOUNDARIES

This section outlines the key assumptions, constraints, and boundary conditions considered for the technical and performance analysis of the hydrogen production system. A dedicated calculation tool has been developed to evaluate both the Levelized Cost of Electricity (LCOE) and the Levelized Cost of Hydrogen (LCOH) under varying scenarios and input parameters. In particular, the section details the criteria used in both scenarios analyzed, including the hydrogen consumption estimates for mobility and industrial applications, the production strategy adopted, and the main outcomes derived from the modelling process. These considerations provide the foundation for evaluating the system's feasibility and guiding future decision-making.

To assess energy supply conditions, three different PPA (Power Purchase Agreement) price scenarios have been defined: the current market price and two future-oriented price projections considered more favorable for long-term planning.

The sizing of the hybrid photovoltaic installation linked to the electrolyzer is also considered a key variable. In this analysis, a preliminary PV capacity of 4 MW has been selected, although this may be adjusted in future iterations based on spatial, technical, or regulatory constraints.

Hydrogen production has been evaluated across multiple time resolutions — hourly, daily, and annual — and expressed in terms of kilograms of hydrogen (kg H_2) produced, to capture seasonal and operational variability in performance.

Additionally, the analysis incorporates potential impacts related to inflation, electricity price evolution, and system degradation over time, all of which may influence the long-term viability and competitiveness of the proposed solution.

Levelized cost of Hydrogen LCOH

LCOH is a method used to assess the total expenses involved in hydrogen production throughout its entire life cycle, including both capital costs (CAPEX) and operating costs (OPEX). It allows us to calculate the break-even point of the project by also considering the cost associated with financing the production unit.

$$LCOH = \frac{CAPEX + \sum \frac{OPEX}{(1+WACC)^t}}{\sum \frac{Producción}{(1+WACC)^t}} \ [€/kg\ H_2]$$

WACC: Weighted Average Cost of Capital
Production: corresponds to the amount of hydrogen produced
t: Project duration (in years)

The LCOH concept does not explicitly describe the cost of hydrogen production, but rather the sale value of the product in which the project begins to be profitable. That is, it represents the break-even point which allows us to know the moment in which a company's income covers its fixed and variable expenses.

Capital costs (CAPEX)

To obtain the value of the levelized cost of hydrogen, the operating costs for each of the years of project operation (transferred to present value) are added to the capital expenditures (CAPEX) and these are divided by the sum of the annual production, bringing each production estimate to a current value.

To estimate the capital cost of the project, the following elements are included:

- Electrolyzer Cost Based on Technology
  - PEM
  - Alkaline.
  - Stack replacement cost
- 4 MW photovoltaic plant
- Auxiliary Equipment:
  - Compressor
  - Water Treatment System
  - Control Systems
  - Cooling System
- Engineering Costs
- Land costs

Operating costs (OPEX)

The estimate of operating costs for the first year of operation of the facility considers the following points:

- Cost of electrical energy consumed by:
  - Electrolyser
  - Auxiliary equipment
- Maintenance and repairs
- Staff and Workforce
- Plant Availability
- Water consumption
  - Hydrogen Production
  - Cooling Systems

In the scenario where the installation of a photovoltaic unit is considered, an annual degradation of 0.5% in the production of solar cells is estimated. This reduction in photovoltaic production is offset by higher electricity consumption from the distribution network. Both the degradation of the photovoltaic plant and the degradation of the electrolyzer are compensated with energy purchased through a PPA, this increase is evaluated each year of operation based on the established degradation parameters.

Electricity prices were defined based on a PPA under three cost scenarios: €50, €60 and €70 per MWh. The €50/MWh and €60/MWh values represent two optimistic scenarios for future electricity price negotiations, while the €70/MWh scenario reflects current market conditions.

In the scenarios where the implementation of a photovoltaic plant with a capacity of 4 MW is considered, the energy consumption of the grid is estimated by subtracting the energy supplied by the photovoltaic from the total consumption to satisfy the established production. Solar production is estimated based on the geographical location of the installation and solar irradiance information obtained from public sources.

Plant availability is estimated considering the different time windows in which the unit is not available for hydrogen production. For the different scenarios analyzed, it was considered that 95% of a calendar year the plant would be out of operation due to maintenance issues or other conditions.

Operating costs are evaluated for the first year of operation of the facility and are increased each year considering average inflation over the entire useful life of the project.

Production

Hydrogen production is estimated based on an average electrolyzer operation at 86% of its nominal daily capacity. Although the electrolyzer is designed for a maximum production of 2,125 kg/day, a more conservative approach has been adopted to reflect realistic operating conditions. This corresponds to an average production rate of 76 kg/h over the year. This high plant utilization factor is enabled by the implementation of a Power Purchase Agreement (PPA), which ensures a stable and continuous electricity supply to the facility. As a result, the variability typically associated with photovoltaic generation throughout the day does not impact the operation of the electrolyzer, allowing for consistent hydrogen output regardless of solar fluctuations.

Electrolyzer degradation is considered to be within the range of 1% per year, with a stack replacement every ten years. In this case, it is considered that the degradation of the stack is compensated by a higher consumption of electrical energy to keep production stable during the year. It is considered that when the stack is replaced, the efficiency of the electrolyzer will return to 100%, starting the gradual reduction of efficiency each year until the next replacement.

In all scenarios, a hydrogen storage tank is considered to buffer production and manage supply logistics. The tank's capacity is determined by the number of autonomy hours required and the average hourly production rate. In this case, an autonomy period of 6 hours has been selected as a reference value. This means that hydrogen can be stored for six hours of continuous production, accommodating variations in transport logistics depending on the size of the transport tanks and the frequency of collection.

The storage system operates at a pressure of 80 bar and is dimensioned based on the maximum production rate of 76 kg H_2/h. Taking into account the autonomy period and including a small oversizing margin for safety, the required tank capacity has been set at 500 kg of hydrogen across all three scenarios considered.

Considerations for hydrogen demand in mobility

For the mobility case, the number of flights arriving at Malpensa Airport was analyzed over a typical year to determine the average monthly traffic.

Regarding bus autonomy, Lhyfe's website (H_2 products – lhyfe-heroes.com) states that each bus has a range of 500 km and can store 37.5 kg of hydrogen in its tank.

Similarly, for the two hydrogen-powered cars assigned to airport staff, we considered their autonomy (350 km) and tank capacity (5.1 kg H_2). The average distance each vehicle is expected to travel was estimated and then multiplied by the number of vehicles to determine total consumption.

Based on this data, the estimated hydrogen demand for mobility applications—such as buses and specialized airport mobility vehicles—is at least 30 kg H_2/h.

We have restricted the flight schedules, assuming operations will be from 7 am to 11 pm. Therefore, during the hours outside this range, the demand will be 0 kg H_2/h.

Considerations for hydrogen demand in Industry

An example industrial facility has been considered, operating 24 hours a day, seven days a week. However, scheduled production stops have been included to account for workers' holidays during the second half of August and the second half of December, resulting in an annual operation between 330 and 347 days, depending on the specific case studied.

Based on the industrial profiles previously analyzed (see Table 5) and their estimated average hydrogen consumption, it is evident that the electrolyzer's output would not be sufficient to fully meet the needs of large-scale consumers, such as steel mills. In other words, within the current framework of this project, supplying such energy-intensive industries is not feasible.

However, in order to ensure continuous operation of the hydrogen production system and maintain a realistic balance between supply and demand, it is proposed to consider at least 40 kg H_2/h to be allocated for industrial use. This value serves as a representative demand level for modelling purposes and allows for flexible integration with other potential consumers.

Financial parameters

The tool considers the following financial parameters to determine the levelized cost of hydrogen production:

- Amortization / Useful life: it is considered a period of useful life of the Hydrogen production asset. Typically it takes 30 years, which can be modified depending on the project.
- Inflation: the cost of production in the first year increases during each year of the project's life due to an inflation factor.
- Weighted Average Cost Of Capital (WACC): it is the rate of return that a company needs to achieve to cover the financing costs of its investments; It includes the interest required by bank financing and the expected profit on the money invested by shareholders.

SCENARIO A (2024): POWERED EXCLUSIVELY BY PPA

In scenario A, the idea is proposed that electricity be supplied through a PPA, in other words, from the grid. For the calculation of the LCOH price and a series of other data, the electricity prices mentioned previously in Table 3 have been used. We have determined an average price for two time slots, the so-called 'peak hours' (8 am - 7 pm) with a price designated as P1=135 €/MWh and the so-called 'off-peak hours' (7 pm - 8 am) with a price P2=64 €/MWh.

For both scenarios there are 10 buses and 2 vehicles from Malpensa Airport. An approximate consumption for the remaining hydrogen used in industry has also been considered (this will be explained later).

SCENARIO B (2024): HYBRID POWERED BY PPA + 7.5 MW OF PHOTOVOLTAIC

For scenario B, the electricity will come from a hybrid system, meaning grid energy (PPA) and a 7.5 MW photovoltaic plant. Initially, this photovoltaic plant has a capacity of 15 MW; however, the airport uses half of this generation, so for practical purposes, it is considered that we hace an installed capacity of 7.5 MW.

The electricity prices for the PPA considerated are the same as scenario A, it means the prices in Table 3.

SCENARIO C (2024): HYBRID POWERED BY PPA + 7.5 MW OF PHOTOVOLTAIC WITH FULL PRODUCTION

For scenario C, the same assumptions as in Scenario B have been applied. The only difference in this case is that the hydrogen production always is going to be the maximum capacity, 76 kg H_2/h at any hour, independent of the H_2 demand.

The electricity prices for the PPA considerated are the same as scenario A and B, it means the prices in Table 3.

SCENARIO 1 (2025): POWERED EXCLUSIVELY BY PPA

In this scenario 1, the proposed condition is that electricity will be supplied through a Power Purchase Agreement (PPA), delivered from the grid according to the planned production. As part of the analysis, current PPA market prices in Italy have been reviewed and used as input for the calculation tool. For the estimation of the Levelized Cost of Hydrogen (LCOH) and related indicators, the electricity price has been set at 70 €/MWh to reflect the current market conditions, while two optimistic price scenarios of 60 €/MWh and 50 €/MWh have also been considered for comparative purposes.

Hydrogen production is set at 76 kg/h, corresponding to the operational output reference established for the electrolyzer. This production level is designed to meet the projected hydrogen demand from both the mobility and industrial sectors identified within the project's area of influence. A built-in safety margin is included to ensure consistent availability and secure supply under standard operating conditions.

Production is stable throughout the 24 hours of the day due to grid connection and the PPA availability that ensures continuous supply. Energy consumption considers electricity to perform the electrolysis of water, and the auxiliaries required.

SCENARIO 2 (2025): HYBRID POWERED BY PPA + 4 MW OF PHOTOVOLTAIC

In this scenario 2, the analysis explores the impact of hybridizing the electricity supply by integrating an on-site photovoltaic (PV) plant alongside the existing Power Purchase Agreement (PPA). Electricity is still primarily sourced from the grid through the PPA according to the planned production schedule. However, the addition of PV generation introduces potential cost savings and flexibility.

For the estimation of the Levelized Cost of Hydrogen (LCOH) and related performance indicators, the electricity price has been set at 70 €/MWh to reflect current market conditions, while two more optimistic scenarios at 60 €/MWh and 50 €/MWh are also evaluated. These values are based on a review of current PPA market prices in Italy and have been integrated into the techno-economic calculation tool.

Hydrogen production is set at 76 kg/h, corresponding to the reference operational output established for the electrolyzer. This production level is designed to meet the projected hydrogen demand from both the mobility and industrial sectors identified within the project's area of influence. A built-in safety margin is included to ensure consistent availability and secure supply under standard operating conditions.

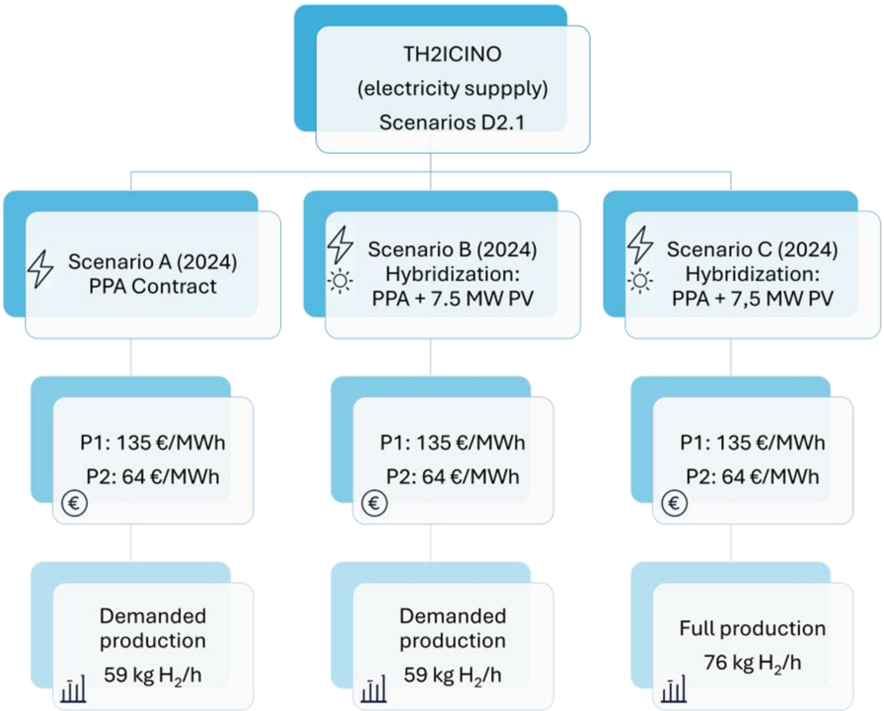
Energy consumption considers electricity to perform the electrolysis of water, and the auxiliaries required is supplied by a photovoltaic unit of 4 MW. And the rest of the required energy is supplied from the grid.

Production is stable throughout the 24 hours of the day due to grid connection and the PPA availability that ensures continuous supply even during low photovoltaic production.

PLANIFICATION AND RESULTS D2.1 (2024)

This section presents the results and key performance indicators obtained using the techno-economic calculation tool for the initial scenarios under study. The analysis considers different electricity supply configurations, including scenarios where the energy comes exclusively from a Power Purchase Agreement (PPA), as well as hybrid scenarios combining PPA with on-site photovoltaic (PV) generation. These results are based on estimated electricity generation volumes and projected PPA price levels.

FIGURE 10: INITIAL SCENARIOS DEVELOPED FOR DELIVERABLE D2.1 (2024)

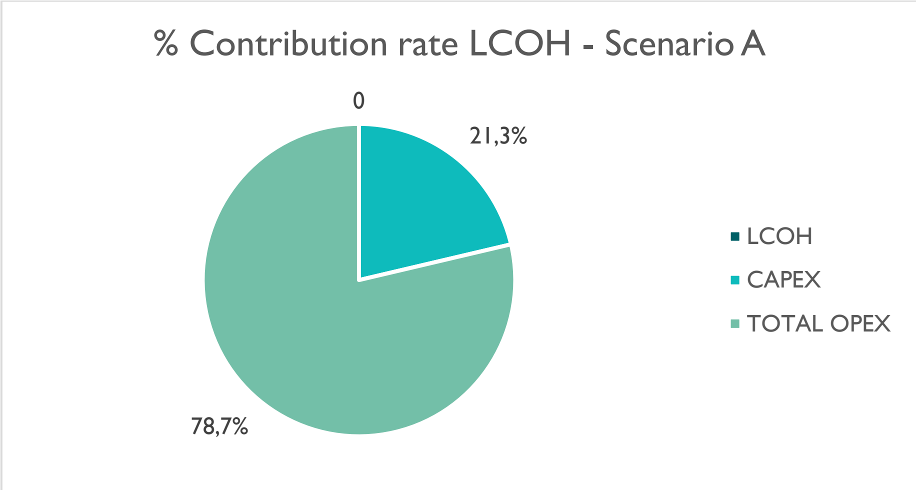


RESULTS OF SCENARIO A (2024): POWERED EXCLUSIVELY BY PPA

TABLE 7: RESULTS OF SCENARIO A (2024): POWERED EXCLUSIVELY BY PPA

	Results
H2 production	503.360 kg/year
Operation hours	8.504 h/year
Grid electricity consumption	60.403 MWh/year
Discharge to grid	0 MWh/year
Grid electricity cost	3.164.354 €/year
Average percentage of electrolyzer use	69 %
Average % of tank storage	69,15 %
LCOH	**10,21 €/kg H_2**

FIGURE 11: RATE CONTRIBUTION RATE OF SCENARIO A (2024)



For the calculation of the LCOH, the following formula has been used:

$$LCOH = \frac{CAPEX + [\Sigma\, OPEXt/(1 + WACC^t)]}{\Sigma\, \text{Production}/(1 + WACC^t)} = €/kg$$

Where:

- WACC is the discount rate
- Production corresponds to the amount of hydrogen produced
- t is the project duration (in years)

For the CAPEX study, the following considerations have been taken:

- cost of the electrolyzer
- stack replacement
- water tanks
- hydrogen tanks
- compressors
- osmosis equipment
- other spare parts

In addition, for the OPEX study, the following has been considered:

- annual electrolyzer costs
- personnel costs
- electric/water consumption

These considerations are the same for all scenarios.

FIGURE 12: CAPEX CONTRIBUTION RATE IN SCENARIO A (2024)

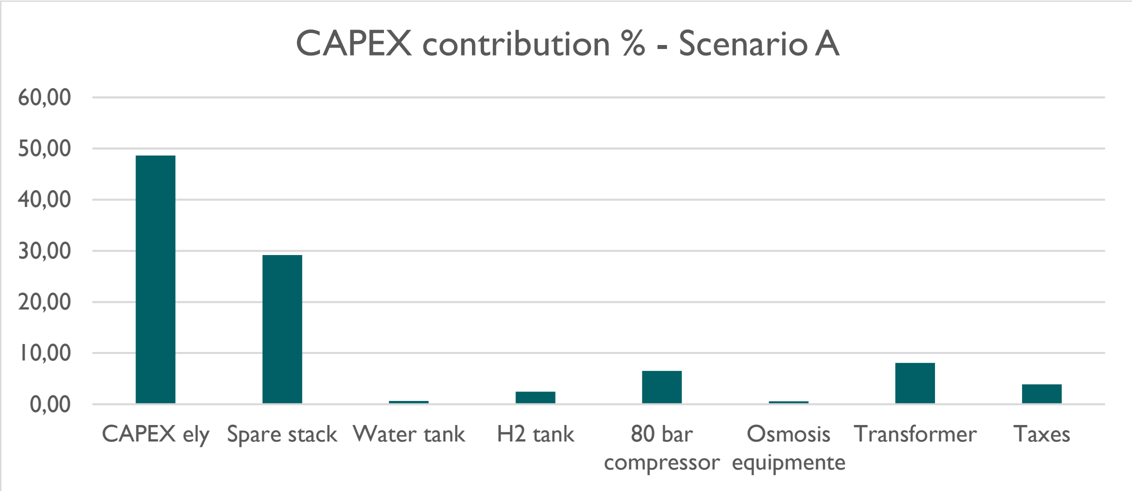
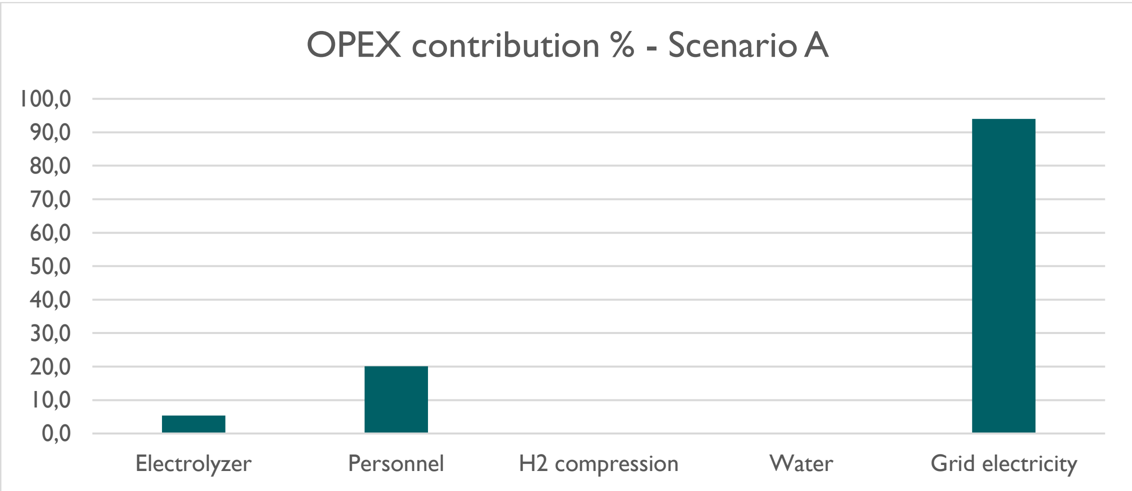


FIGURE 13: OPEX CONTRIBUTION RATE IN SCENARIO A (2024)

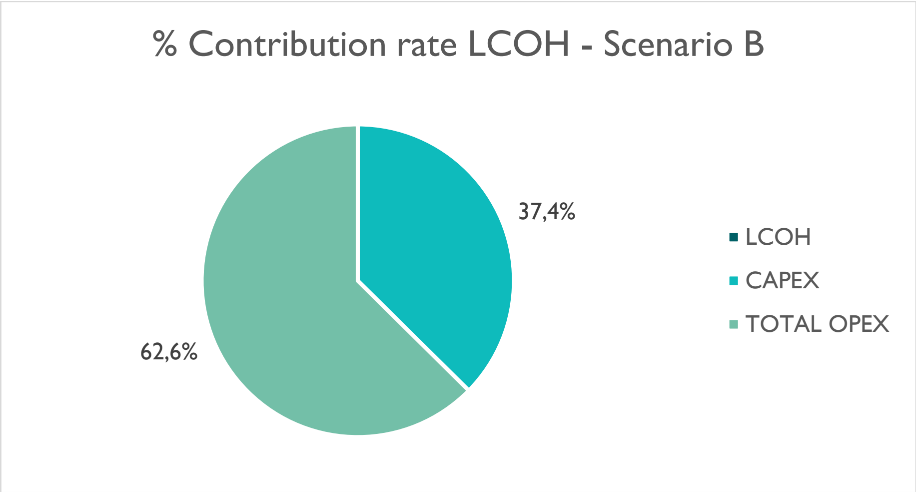


RESULTS OF SCENARIO B (2024): POWERED BY PPA + 7.5 MW OF PHOTOVOLTAIC

TABLE 8: RESULTS OF SCENARIO B (2024): POWERED BY PPA + 7.5 MW OF PV

	Results
H2 production	503.360 kg/year
Operation hours	8.504 h/year
PV production	44.121 MWh/year
Grid electricity consumption	16.012 MWh/year
Discharge to grid	29.848 MWh/year
Grid electricity cost	1.352.364 €/year
Average % of electrolyzer use	69 %
Average % of tank storage	69,15 %
LCOH	7,61 €/kg H2

FIGURE 14: RATE CONTRIBUTION RATE IN SCENARIO B (2024)



For the calculation of the LCOH, the formula and considerations are the same as in the previous scenario A. However, for CAPEX and OPEX, the following must be considered: For CAPEX, the cost of the photovoltaic system; and for OPEX, the photovoltaic plant and the land where it is installed must also be considered.

FIGURE 15: CAPEX CONTRIBUTION RATE IN SCENARIO B (2024)

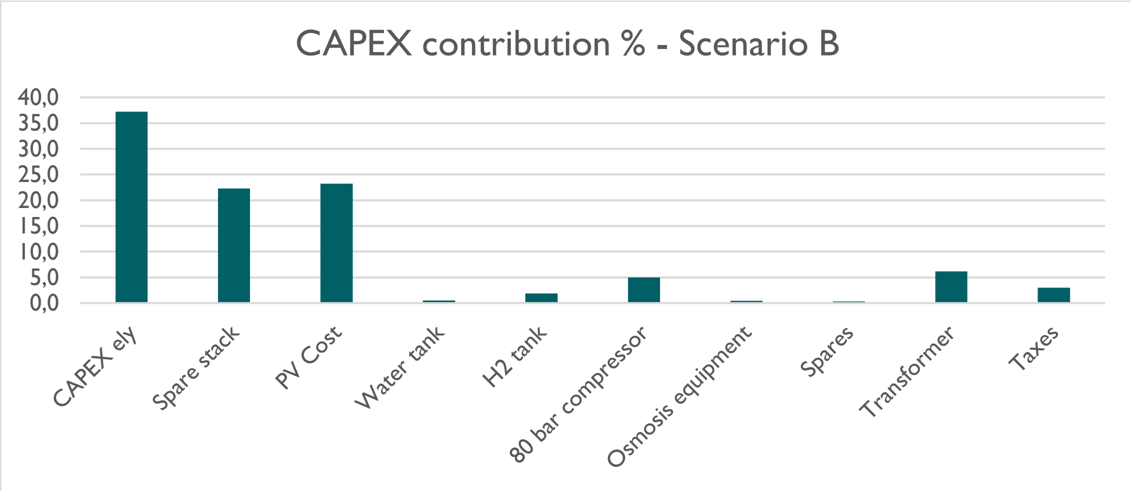
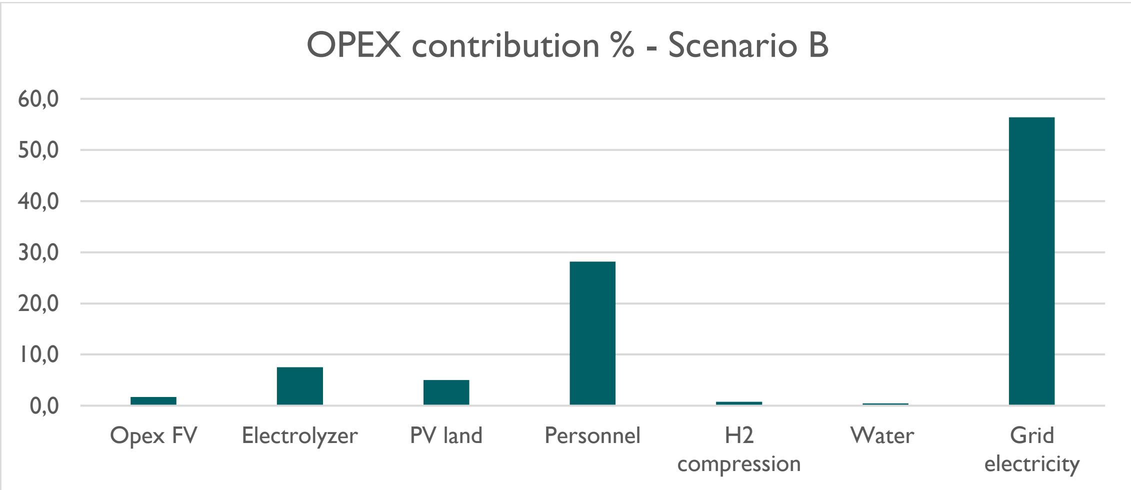


FIGURE 16: OPEX CONTRIBUTION IN SCENARIO B (2024)



RESULTS OF SCENARIO C (2024): POWERED BY PPA + 7.5 MW OF PHOTOVOLTAIC WITH FULL PRODUCTION

TABLE 9: RESULTS OF SCENARIO C (2024): POWERED BY PPA + 7.5 MW OF PV WITH FULL PRODUCTION

	Results
H2 production	663.860 kg/year
Operation hours	8.735 h/year
PV production	44.121 MWh/year
Grid electricity consumption	23.881 MWh/year
Discharge to grid	28.170 MWh/year
Grid electricity cost	1.922.034 €/year
Average percentage of electrolyzer use	91 %
Average % of tank storage	91,2 %
LCOH	**6,64 €/kg H2**

The same considerations of scenario B has been taken for the calculation of these parameters.

FIGURE 17: RATE CONTRIBUTION RATE OF SCENARIO C (2024)

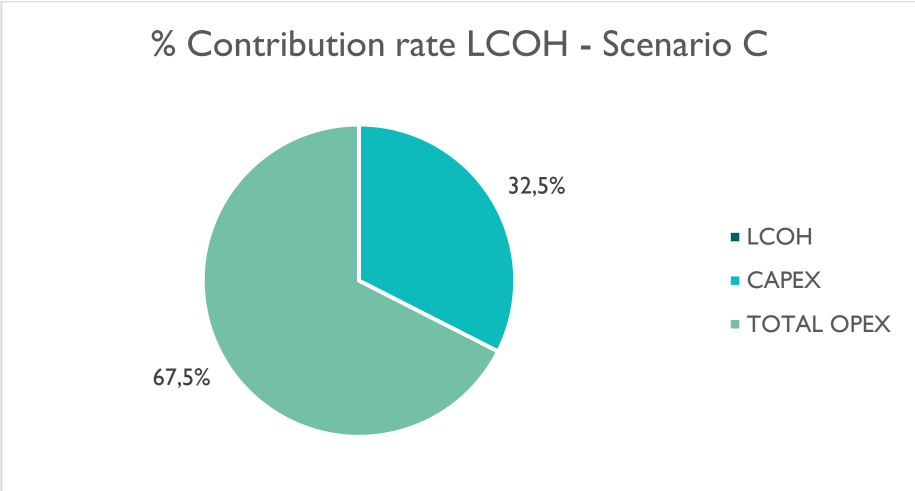


FIGURE 18: CAPEX CONTRIBUTION RATE IN SCENARIO C (2024)

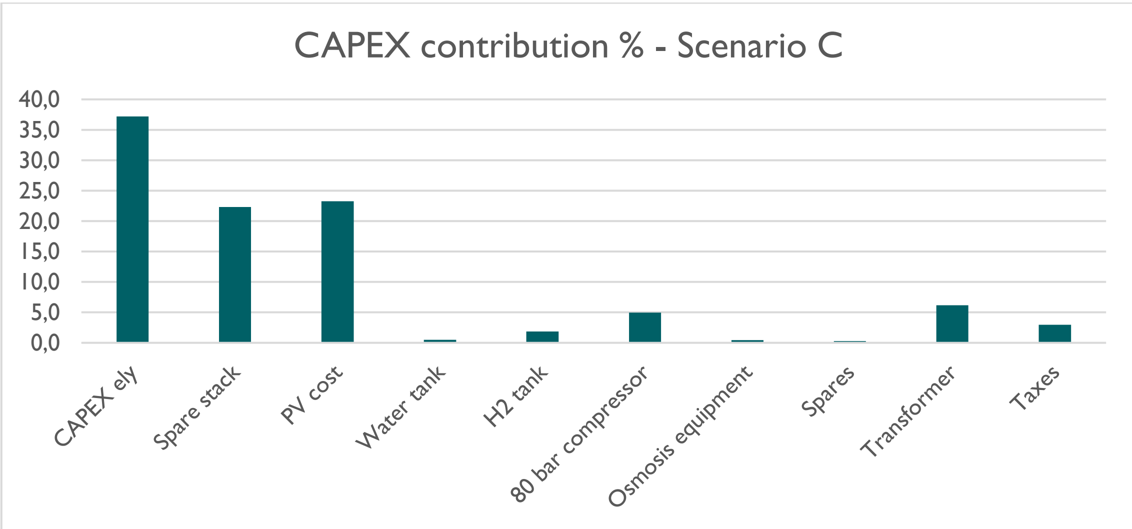
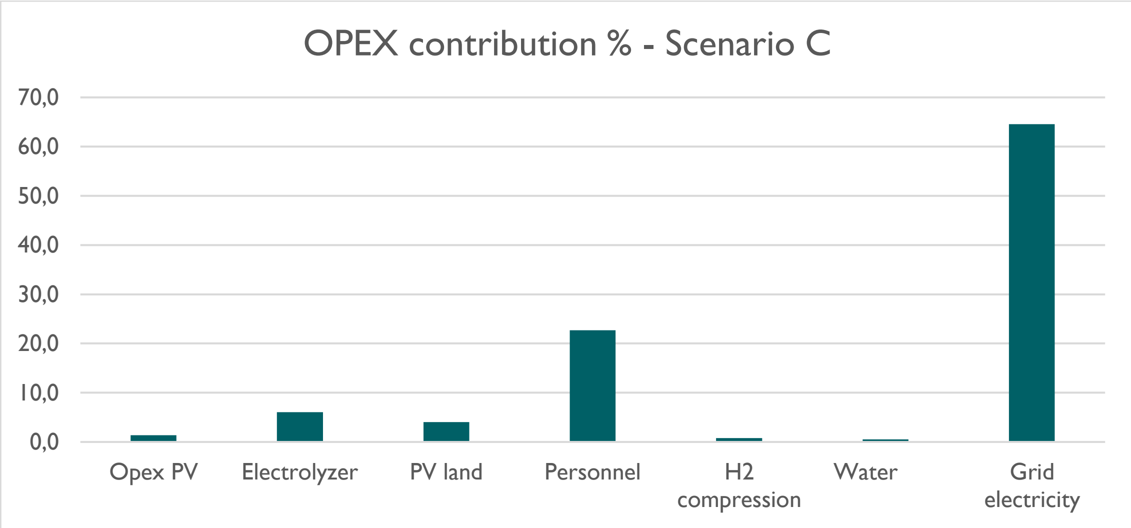


FIGURE 19: OPEX CONTRIBUTION RATE IN SCENARIO C (2024)



GENERAL RESULTS DELIVERABLE D2.1 (2024)

TABLE 10: GENERAL RESULTS FOR SCENARIOS DELIVERABLE 2.1 (2024)

	Results Scenario A	**Results Scenario B**	**Results Scenario C**
H2 production	503.360 kg/year	503.360 kg/year	663.860 kg/year
Operation hours	8.504 h/year	8.504 h/year	8.735 h/year
PV Production	-	44.121 MWh/year	44.121 MWh/year
Grid electricity consumption	60.403 MWh/year	16.012 MWh/year	23.881 MWh/year
Discharge to grid	0 MWh/year	29.848 MWh/year	28.170 MWh/year
Grid electricity cost	3.164.354 €/year	1.352.364 €/year	1.922.034 €/year
Average percentage of electrolyzer use	69 %	69 %	91 %
Average rate of tank storage	69,15%	69,15%	91,2%
LCOH	**10,21 €/kg H_2**	**7,61 €/kg H_2**	**6,64 €/kg H_2**

As can be seen in Table 10, the LCOH price goes from higher to lower depending on the scenario. Make sense that the lowest price is in scenario C, as this is where we produce the most hydrogen making cheaper the cost.

To achieve the project's objective, which is to bring a LCOH price below 4,5 €, the prices of the PPAs have been set to achieve this goal.

Table 11 shows the hydrogen price for derived cases referenced to scenarios A and B where the LCOH is fixed at or below 4.5 €/kg H_2. In case 2 (with a demanded production), the expected prices are not obtained, as the costs of photovoltaics prevent a hydrogen price below the target price.

TABLE 11: PPAS NEEDED FOR LCOH PRICES BELOW 4,5 €/KG

Case 1 (Referenced to Scenario A)		**Case 1 with full production (Referenced to Scenario A)**	
PPA	**Target LCOH**	**PPA**	**Target LCOH**
10 €/MWh	4,5 €/kg H_2	28 €/ MWh	4,5 €/kg H_2
5,9 €/MWh	4,25 €/kg H_2	24 €/ MWh	4,26 €/kg H_2
1,8 €/MWh	4,01 €/kg H_2	20 €/ MWh	4,07 €/kg H_2
Case 2 (Referenced to Scenario B)		**Case 2 with full production (Referenced to Scenario B)**	
PPA	**Target LCOH**	**PPA**	**Target LCOH**
In this case, no PPA achieves an LCOH below 4.50 €/kg H_2. Even under conditions with PV-only electricity supply, the costs remains above this threshold.		23 €/ MWh	4,5 €/kg H_2
		15 €/ MWh	4,26 €/kg H_2
		9,5 €/ MWh	4,07 €/kg H_2

As shown in Table 11, the PPA prices obtained are not considered fully realistic, prompting a revision of the initial assumptions and boundary conditions.

For the new derived cases, a target PPA price of 44 €/MWh has been established. Additionally, it was checked that in Case 2 it was not possible to reach the objective of an LCOH below €4.50/kg, mainly due to the high costs associated with the photovoltaic (PV) system. To address this limitation, a reduction in the PV plant size to 2.5 MW has been proposed as an improvement. This adjustment aims to reduce both capital and operational costs, thereby bringing the LCOH closer to the target threshold.

Moreover, stack degradation has been considered, leading to the evaluation of two additional cases:

- Case 3.1: Powered exclusively by PPA
  - Degradation study with demand for mobility + industry
- Case 3.2: Powered exclusively by PPA
  - Degradation study with maximum production
- Case 4.1: Powered by PPA + 2.5 MW of PV
  - Degradation study with mobility demand + industry
- Case 4.2: Powered by PPA + 2.5 MW of PV
  - Degradation study with maximum production

With all this data, Table 12 is obtained:

TABLE 12: LCOH OF THE IMPROVEMENT SCENARIOS

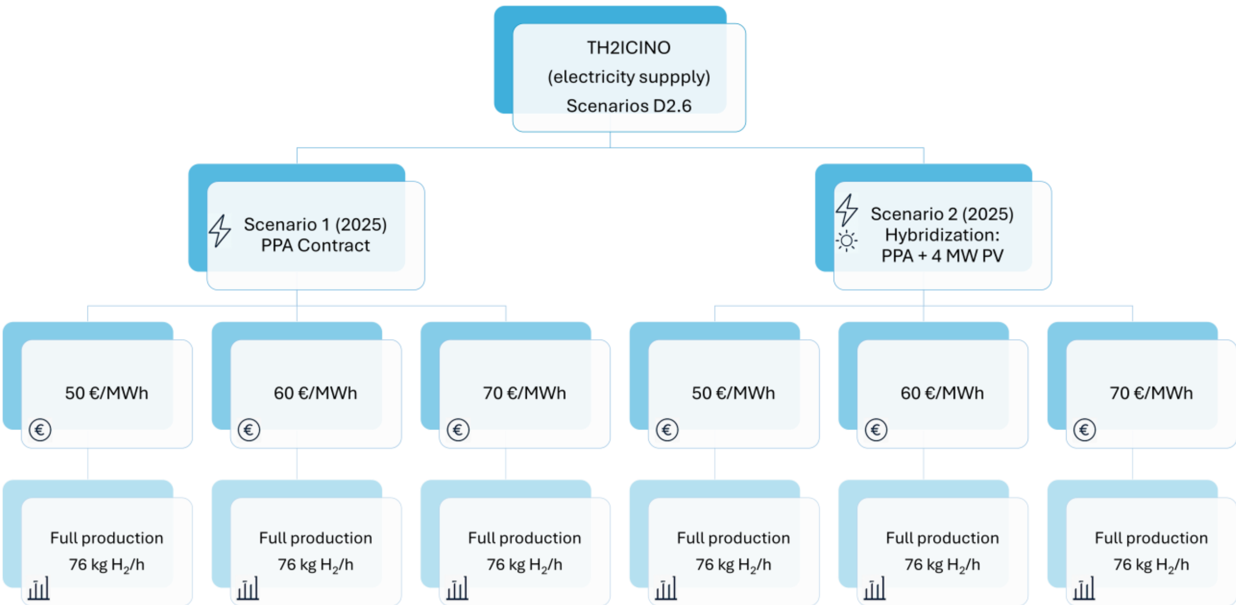
	Case 3.1 (Referenced to Scenario A)	**Case 3.2 Full production (Referenced to Scenario A)**	**Case 4.1 (Referenced to Scenario B)**	**Case 4.2 Full production (Referenced to Scenario B)**
LCOH – stack degradation considered	6,66 €/kg H_2	5,57 €/kg H_2	6,22 €/kg H_2	5,63€/kg H_2

PLANIFICATION AND RESULTS D2.6 (2025)

This section presents the results and key performance indicators obtained using the techno-economic calculation tool for the final scenarios developed. The analysis considers different electricity supply configurations, including scenarios where energy is sourced exclusively through a Power Purchase Agreement (PPA) and hybrid scenarios that combine PPA with on-site photovoltaic (PV) generation.

As part of the analysis, the PV installation size has been optimized to 4 MW, and PPA price assumptions have been updated to reflect current electricity market conditions—with a reference price of 70 €/MWh identified for the Italian PPA market. These results are based on estimated electricity generation volumes and incorporate realistic pricing frameworks to assess the overall viability of each configuration.

FIGURE 20: FINAL SCENARIOS DEVELOPED FOR DELIVERABLE D2.6 (2025)



RESULTS OF SCENARIO 1 (2025): POWERED EXCLUSIVELY BY PPA

Within Scenario 1, three variants have been developed based on different electricity price assumptions under the Power Purchase Agreement (PPA). These variants reflect a progression from the current market price in Italy (70 €/MWh) to more optimistic future scenarios, allowing for a comparative analysis of their impact on hydrogen production costs and system performance.

TABLE 13: RESULTS OF SCENARIO 1 (2025): POWERED EXCLUSIVELY BY PPA WITH FULL PRODUCTION

Scenario	1.1	1.2	1.3	Units
PPA electricity cost	70 €/MWh	60 €/MWh	50 €/MWh	€/MWh
H2 production	7.124.510,70	7.124.510,70	7.124.510,70	kg/year
Operation hours	8.327,00	8.327,00	8.327,00	h/year
PV production	-	-	-	MWh/year
Grid electricity consumption	37.971,12	37.971,12	37.971,12	MWh/year
Discharge to grid	-	-	-	MWh/year
Average percentage of electrolyzer use	91	91	91	%
Average % of tank storage				%
LCOH	9,02	8,24	7,46	**€/kg H2**

FIGURE 21: LCOH CONTRIBUTION RATE IN SCENARIO 1.1 (PPA ELECTRICITY COST 70 €/MWH)

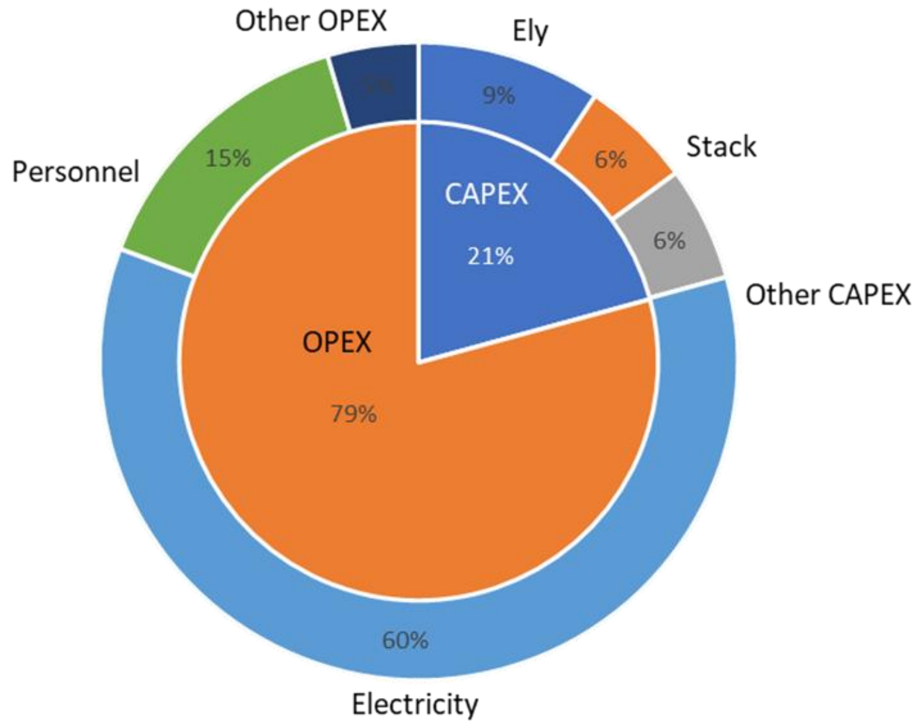


FIGURE 22: LCOH CONTRIBUTION RATE IN SCENARIO 1.2 (PPA ELECTRICITY COST 60 €/MWH)

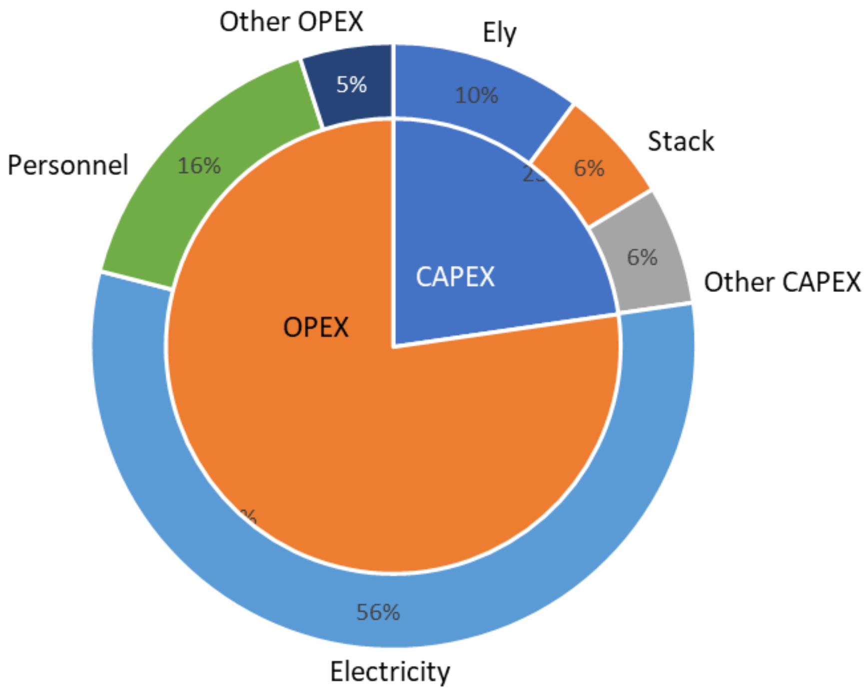
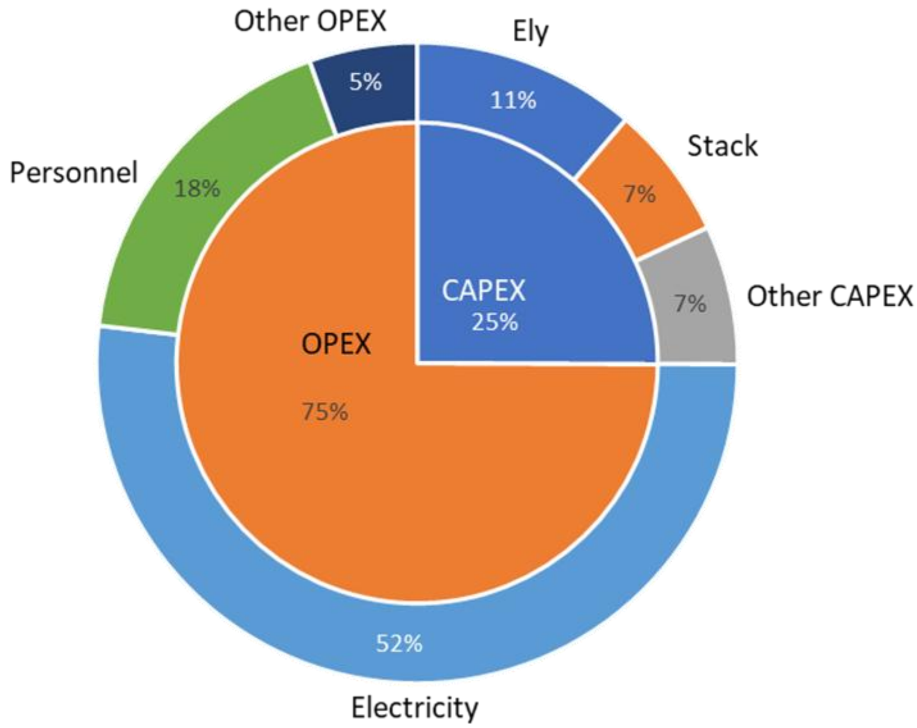


FIGURE 23: LCOH CONTRIBUTION RATE IN SCENARIO 1.3 (PPA ELECTRICITY COST 50 €/MWH)



RESULTS OF SCENARIO 2 (2025): POWERED BY PPA + 4 MW OF PHOTOVOLTAIC

Within Scenario 2, three variants have been developed based on different electricity price assumptions under the Power Purchase Agreement (PPA). These variants range from the current market price in Italy (70 €/MWh) to more optimistic future projections, enabling a comparative evaluation of their impact on hydrogen production costs within a hybrid energy supply configuration.

TABLE 14: RESULTS OF SCENARIO 2 (2025): POWERED BY PPA + 4 MW OF PV WITH FULL PRODUCTION

Scenario	2.1	2.2	2.3	Units
PPA electricity cost	70 €/MWh	60 €/MWh	50 €/MWh	€/MW
H2 production	632.852,00	632.852,00	632.852,00	kg/year
Operation hours	8.327,00	8.327,00	8.327,00	h/year
PV production	5.820,70	5.820,70	5.820,70	MWh/year
Grid electricity consumption	32.150,42	32.150,42	32.150,42	MWh/year
Discharge to grid	-	-	-	MWh/year
Average percentage of electrolyzer use	91	91	91	%
Average % of tank storage				%
LCOH	8,83	8,16	7,49	**€/kg H2**

FIGURE 24: LCOH CONTRIBUTION RATE IN SCENARIO 2.1 (PPA ELECTRICITY COST 70 €/MWH)

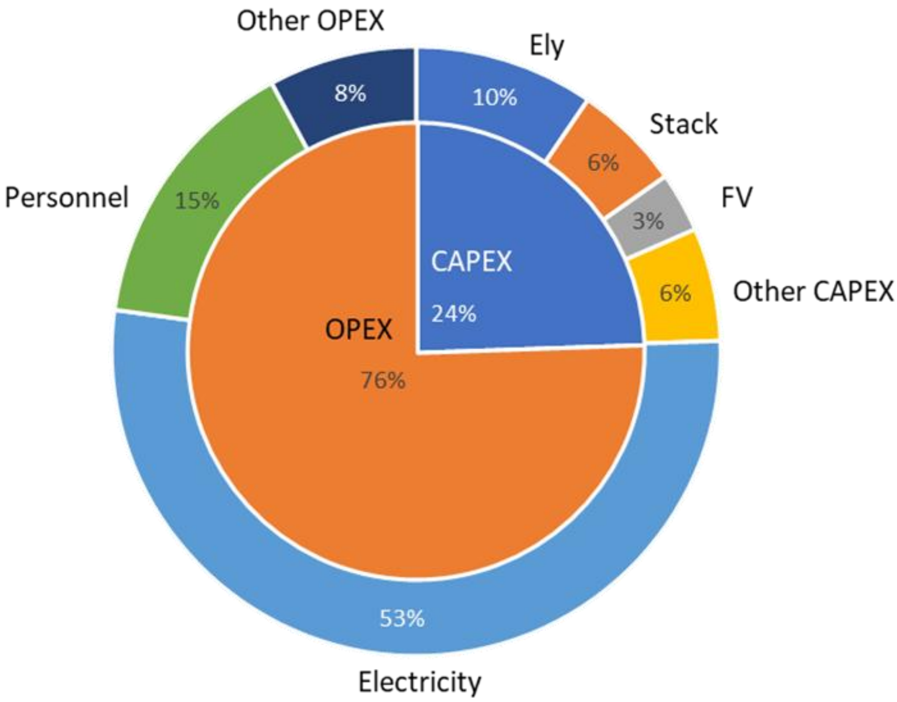


FIGURE 25: LCOH CONTRIBUTION RATE IN SCENARIO 2.2 (PPA ELECTRICITY COST 60 €/MWH)

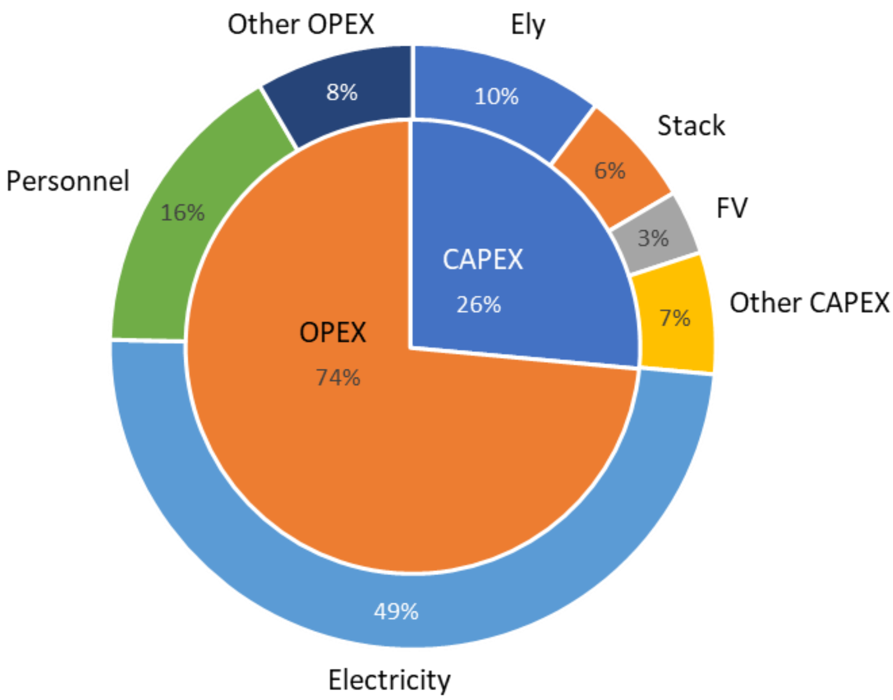
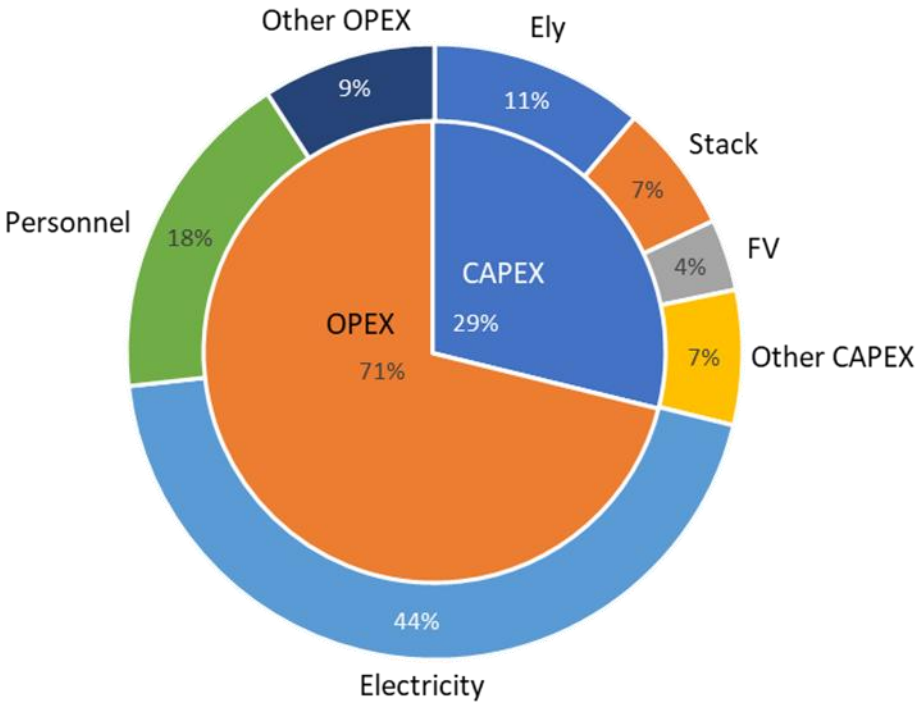


FIGURE 26: LCOH CONTRIBUTION RATE IN SCENARIO 2.3 (PPA ELECTRICITY COST 50 €/MWH)



GENERAL RESULTS DELIVERABLE D2.6 (2025)

The results from Scenarios 1 and 2, developed to assess the impact of different electricity costs under a PPA, are presented in Table 15. The analysis confirms that the integration of a photovoltaic (PV) unit generally improves the hydrogen production cost. In particular, for the case studied with a PPA electricity price of 50 €/MWh (comparing Scenario 1.3 to 2.3), the instalation of a PV slightly increases the value for the LCOH, from 7,46 to 7,49 €/kg, This condition may be a result of the fact that the generation price of photovoltaics is higher than the price of the PPA considered.

TABLE 15: RESULTS OF DIFFERENT SCENARIOS FOR 2025

Case	Scenario	PPA electricity cost €/MWh	LCOH €/kg
PPA	Scenario 1.1	70	9.02
	Scenario 1.2	60	8.24
	Scenario 1.3	50	7.46
PPA + 4 MW of FV	Scenario 2.1	70	8.83
	Scenario 2.2	60	8.16
	Scenario 2.3	50	7.49

As shown in Figure 21 to Figure 26 the main contributor to the hydrogen production cost is the operating expenditure (OPEX), which accounts for an average of 75% of the total cost. Within this, electricity consumption for electrolysis represents approximately 52% of the total hydrogen cost.

In scenarios that include photovoltaic (PV) generation, electricity sourced from the grid contributes 49% to the hydrogen cost, compared to 56% in scenarios where the plant is supplied entirely by grid electricity.

Other OPEX components include utility operations and water consumption, which have a comparatively smaller impact.

Considering the CAPEX components, it can be concluded that the electrolyzer accounts for approximately 4% of the Levelized Cost of Hydrogen (LCOH), while stack replacement contributes around 6% to the total cost of the hydrogen molecule. Overall, capital investment represents 25% of the total hydrogen production cost. Additional CAPEX elements include the compressor, reverse osmosis water purification system, storage tanks, and other supporting infrastructure such as the electrical transformer.

CONCLUSIONS

This final version of the deliverable outlines the operational description and calculation methodology for the planned TH2ICINO facility. It presents various scenarios that compare technological and economic parameters using a dedicated modeling tool. Each scenario is tailored to meet the performance and consumption requirements of TH2ICINO, with the ultimate objective of minimizing the Levelized Cost of Hydrogen (LCOH).

This study has identified the key components required for the technical planning of the TH2ICINO Hydrogen Valley:

- Green energy generation.
- Hydrogen production.
- Hydrogen storage.
- Hydrogen distribution.
- Hydrogen consumption.

Additionally, by integrating technical and economic data from the main equipment and operational facilities, several performance and profitability indicators have been calculated, including the Levelized Cost of Hydrogen (LCOH), electrolyzer utilization rate, and hydrogen storage rate.

However, it is important to highlight that one of the most critical factors influencing the reduction of hydrogen production costs (LCOH) is the price of electricity. The analysis confirms that, under current market conditions in Italy, electricity prices are around 70 €/MWh, which poses a significant barrier to achieving LCOH targets of €4.50/kg at this stage.

DEVIATIONS

No deviations found.

FIGURE 27: TH2ICINO GANTT FOR WP2 (YEAR 1 AND 2)

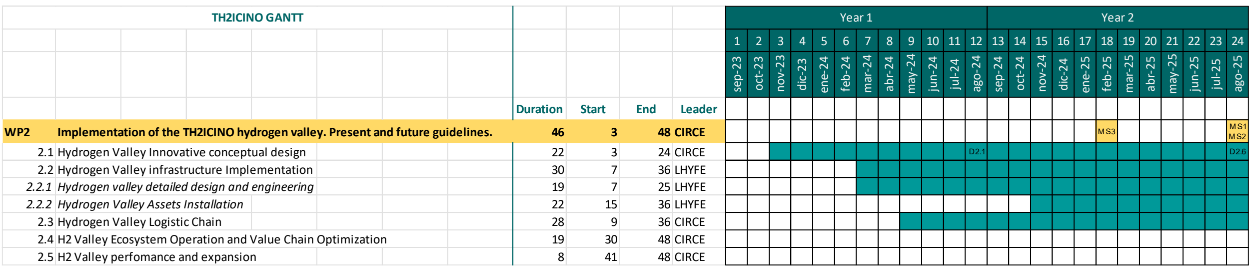
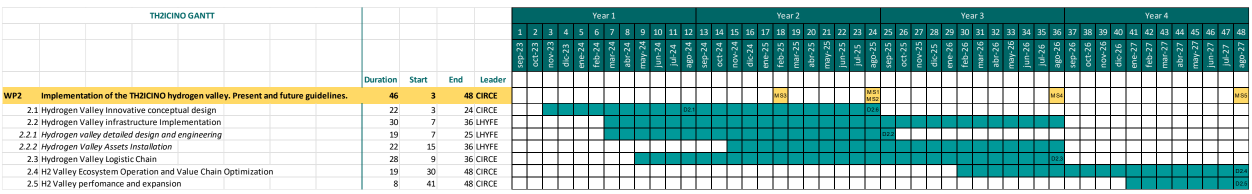


FIGURE 28: TH2ICINO GANTT FOR WP2 (PROJECT)



OBSTACLES

TECHNOLOGY

1. Market difficulties (high price of H2 respect to other fuels/source of energy). Contingency: evaluation of a minimum threshold of H2 production to reach a competitive levelized price.

2. Difficult involvement and low interest by further stakeholders. Mitigation – Increase of communications on specific – more reactive – groups, design and creation of sub-success cases within the demonstrated value chain.

FUTURE TASKS

Deliverables D2.1 and D2.6 (Midterm and Final Versions) provide a concise overview of the Hydrogen Valley design, along with a set of KPIs to quantify the overall performance of the planned deployment.

These documents serve as a foundational reference to guide the strategic planning and implementation of hydrogen infrastructure in the region over the next decade. The outputs aim to support decision-making processes, optimize resource allocation, and ensure that future hydrogen facilities align with regional decarbonization goals and innovation pathways.

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