D2.1 TH2ICINO PLANIFICATION AND KPIS DEFINITION (MID-TERM VERSION)

V5.0

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.
WP5	

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.

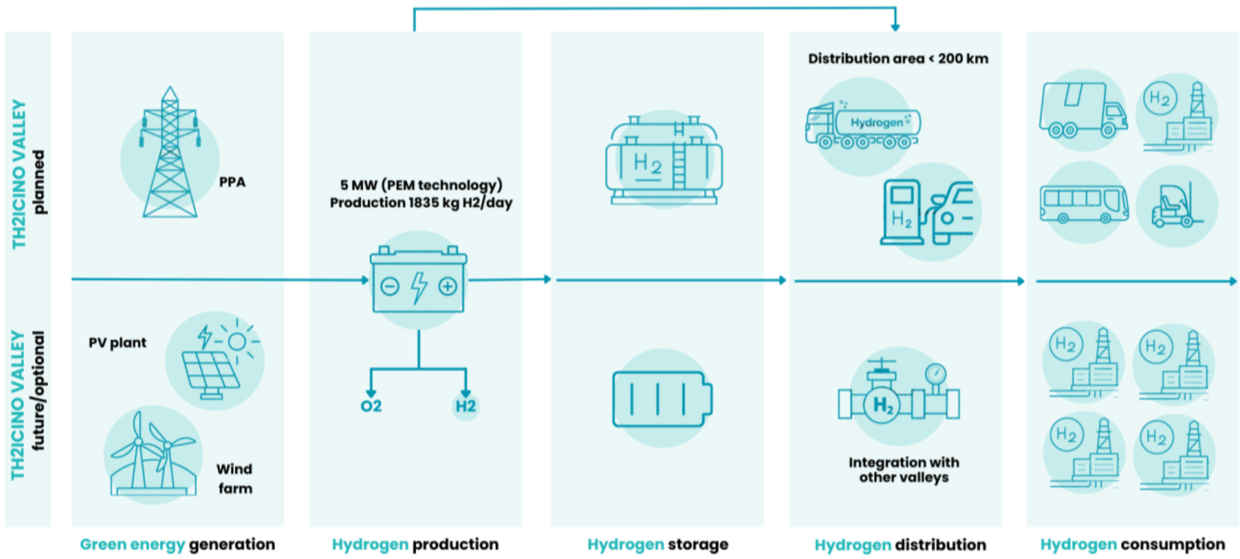


FIGURE 3. CONCEPTUAL DEVELOPMENT OF THE CURRENT AND FUTURE TH2ICINO

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 have 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 below shows the monthly electricity price, which is going to be the estimated PPA prices:

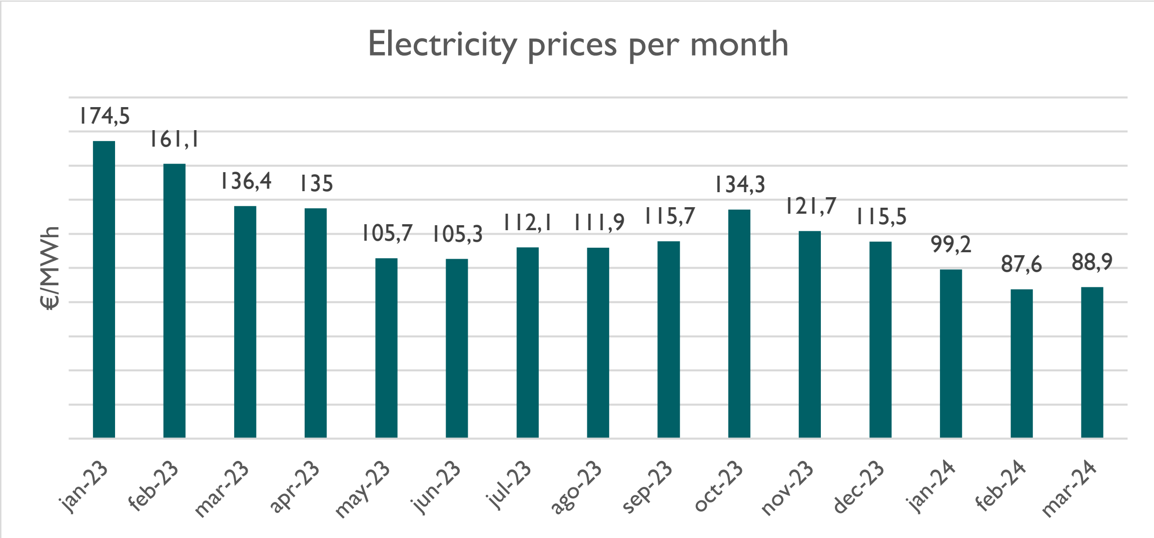


FIGURE 4. ELECTRICITY PRICES PER MONTH = PPA PRICES

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

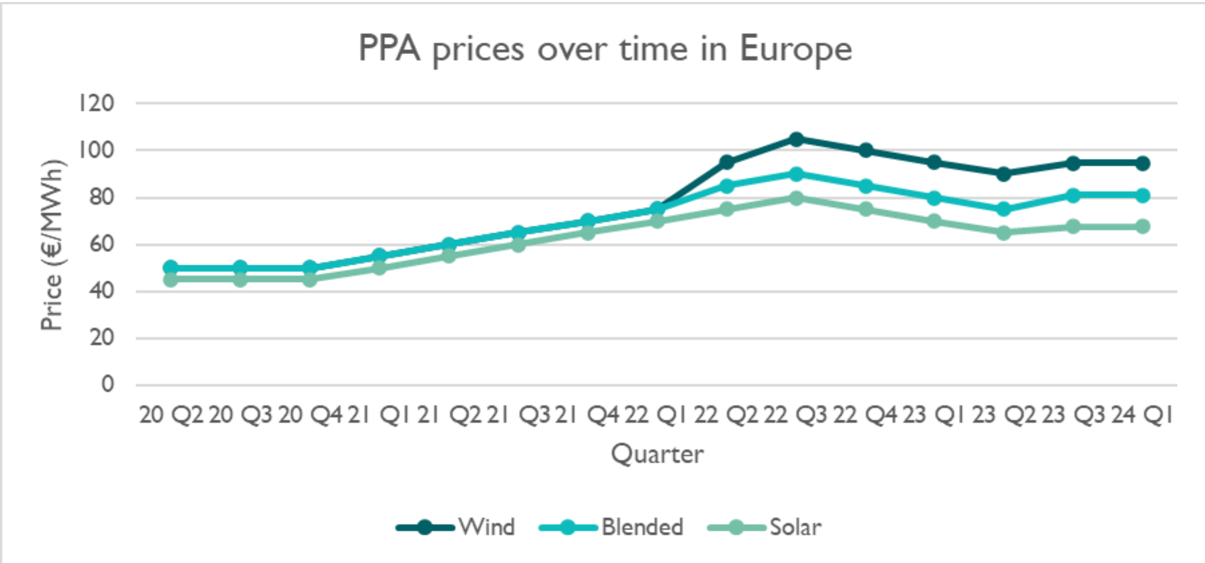


FIGURE 5. PPA PRICES OVER TIME IN EUROPE.

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 of green technology.

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 Nm³ 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 m², 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 pressures, 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's end, according to the results (technical, financial) from those (at least 3) retrofitted within the project.

As shown in Figure 3, 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. POTENTIAL 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 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

SUMMARY TABLE OF THE DIFFERENT DATA PROVIDED BY THE PROJECT AND PARTNERS FOR USE IN THE ANALYSIS TOOL

TABLE 6: COMPARATIVE 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
Mobility vehicules	SEA MILANO	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 compare proposed scenarios in the project, in the mid-term edition are considered:

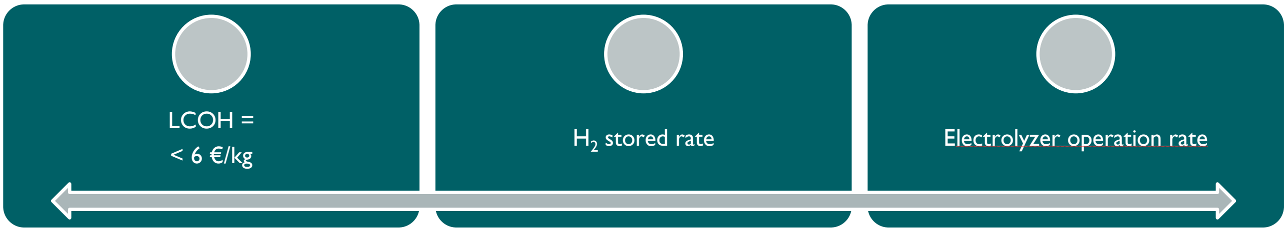


FIGURE 6: KPIS DEFINITION.

- 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

SCENARIO 1: POWERED EXCLUSIVELY BY PPA

In scenario 1, 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=0.135 €/kWh and the so-called 'off-peak hours' (7 pm - 8 am) with a price P2=0.064 €/kWh.

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 2: HYBRID POWERED BY PPA + 7.5 MW OF PHOTOVOLTAIC

For scenario 2, 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 have an installed capacity of 7.5 MW.

The electricity prices for the PPA considered are the same as scenario 1, it means the prices in Table 3.

SCENARIO 3: HYBRID POWERED BY PPA + 7.5 MW OF PHOTOVOLTAIC WITH FULL PRODUCTION

For scenario 3, the same considerations of scenario 2 have been taken. 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_2demand.

The electricity prices for the PPA considered are the same as scenario 1, it means the prices in Table 3.

PLANIFICATION AND RESULTS

This section explains the considerations reflected for both scenarios, what consumption has been considered for mobility and industry, what type of production has been considered and what results have been obtained, etc.

The considerations that have been taken for the consumption of industry and mobility have been the same independent of the electricity source.

In all cases, a tank is considered whose capacity will depend on the hours of autonomy and the average hourly production.

Depending on the size of the transport storage tanks and the periodicity of the transport, more or less hours of autonomy can be chosen. In this case, an autonomy of 6 hours has been chosen as a standard value, i.e. every 6 hours a certain amount of hydrogen can be stored, depending on the scenario in which we find ourselves. This tank will store hydrogen at a pressure of 80 bar.

The size of the tank has been chosen in the situation where 76 kg H2/h are continuously produced, i.e. the maximum hourly production. Considering this maximum hourly production, the hours of autonomy and a small oversizing for safety reasons, we arrive at the conclusion that a 500 kg tank is needed for the three scenarios.

CONSIDERATIONS FOR MOBILITY

For the mobility case, we studied the number of flights arriving at Malpensa airport each month over a typical year to determine the average number of flights.

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

Similarly, for the two cars designated for airport workers, we know their autonomy (350 km) and tank capacity (5.1 kg H_2). We calculated the average distance each vehicle would travel and multiplied it by the number of cars.

With this data, we have determined the following: the estimated demand for mobility (buses + cars) is 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 INDUSTRY

The electrolyzer has a capacity of 5 MW and produces 2125 kg H2/day. However, a reference production of 1835 kg H2/day is used due to potential variations in its operation. With this data, an hourly production of 76 kg H2/h is obtained. This figure has been used to adjust the industry's demand providing an industrial demand figure of 40 kg H_2/h.

We have considered an example industry that operates 24 hours a day, seven days per week. However, we have set out the workers' holidays be the second half of August and the second half of December, during which the factory will stop its production, so the production will be 330 days a year.

Considering the industries studied before (Table 5) and estimating their average hydrogen consumption, it is observed that the electrolyzer would not produce enough to meet their needs. In other words, from this part of the project, we are not capable of supplying this type of industry (a steel mill). However, since the goal is to complete hydrogen production, we consider it appropriate to supply 40 kg H2/h for the industry.

IMPORTANT: In this example, hourly production and demand have been considered, meaning that during the days they operate, they receive 40 kg of H_2 every hour. For future plans, this scheduling will be adjusted.

RESULTS OF SCENARIO 1: POWERED EXCLUSIVELY BY PPA

TABLE 7. RESULTS OF SCENARIO 1 (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**

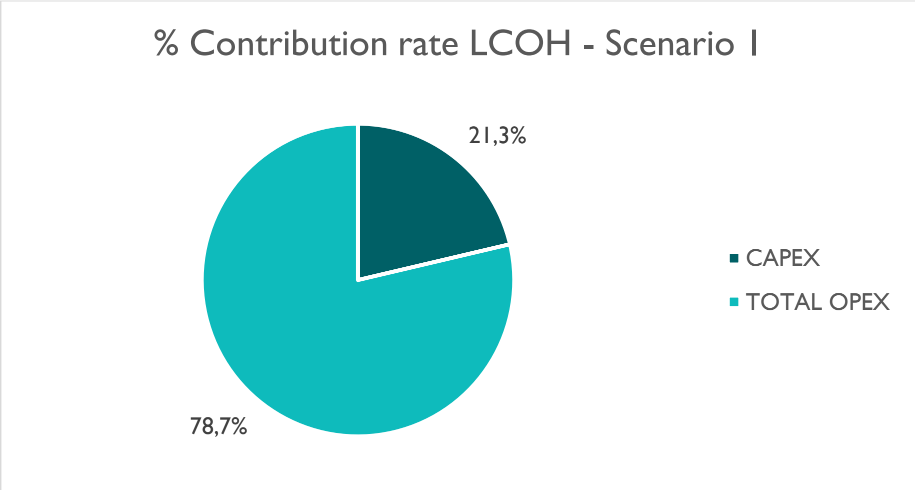


FIGURE 7. RATE CONTRIBUTION RATE OF SCENARIO 1

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

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

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 both scenarios with a little difference, it will be seen later.

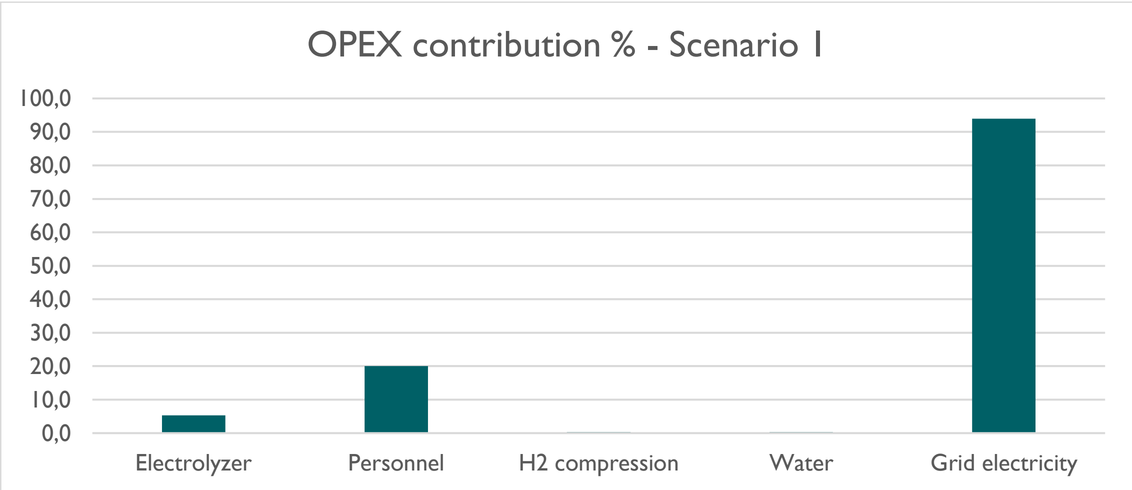


FIGURE 8. OPEX CONTRIBUTION RATE IN SCENARIO 1

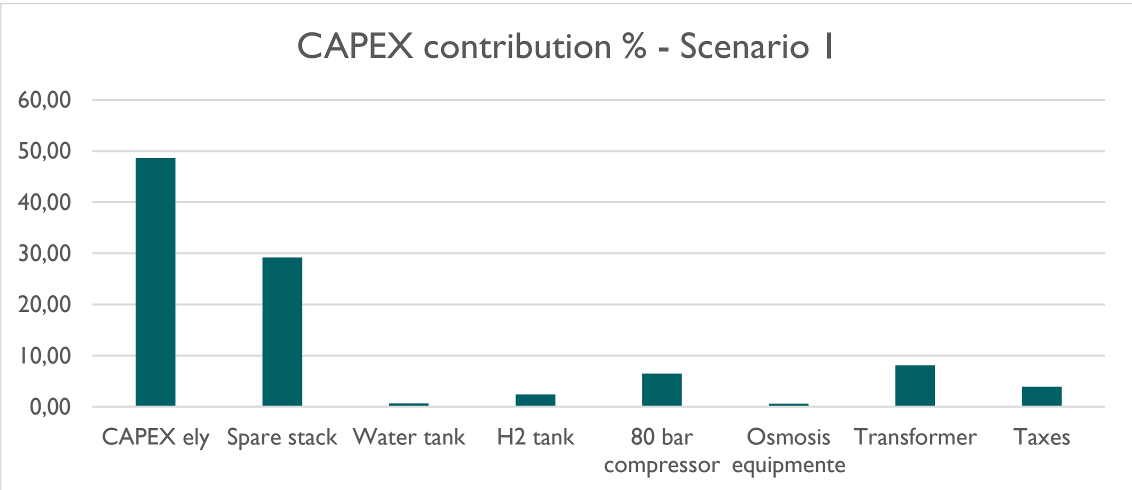


FIGURE 9. CAPEX CONTRIBUTION RATE IN SCENARIO 1

RESULTS OF SCENARIO 2: POWERED BY PPA + 7.5 MW OF PHOTOVOLTAIC

TABLE 8. RESULTS OF SCENARIO 2 (PPA+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 H_2**

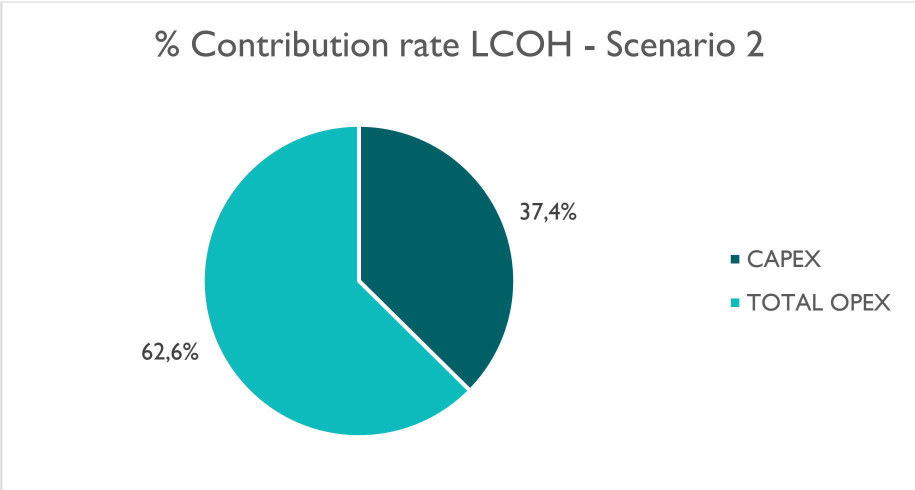


FIGURE 10. RATE CONTRIBUTION RATE IN SCENARIO 2

For the calculation of the LCOH, the formula and considerations are the same as in the previous scenario. 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.

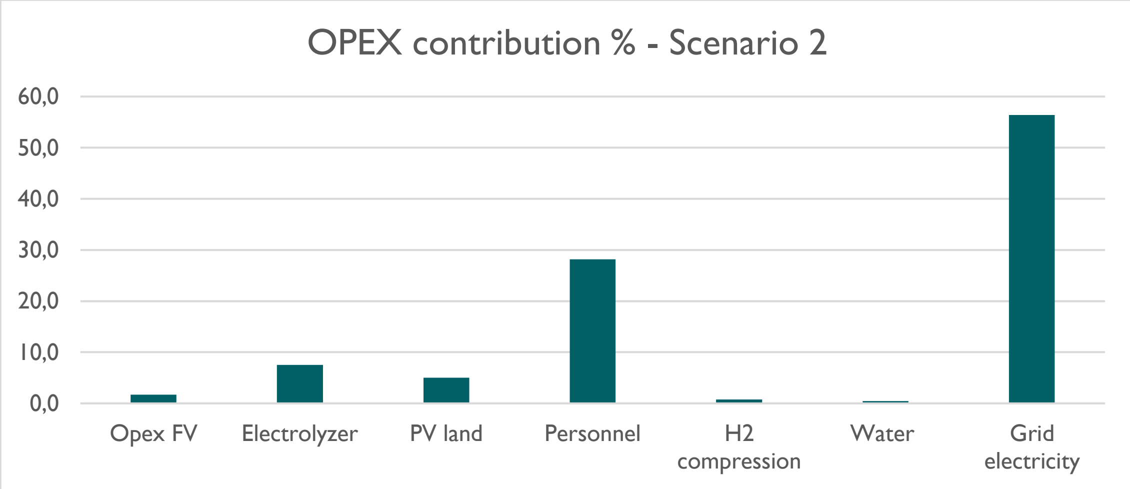


FIGURE 11. OPEX CONTRIBUTION IN SCENARIO 2

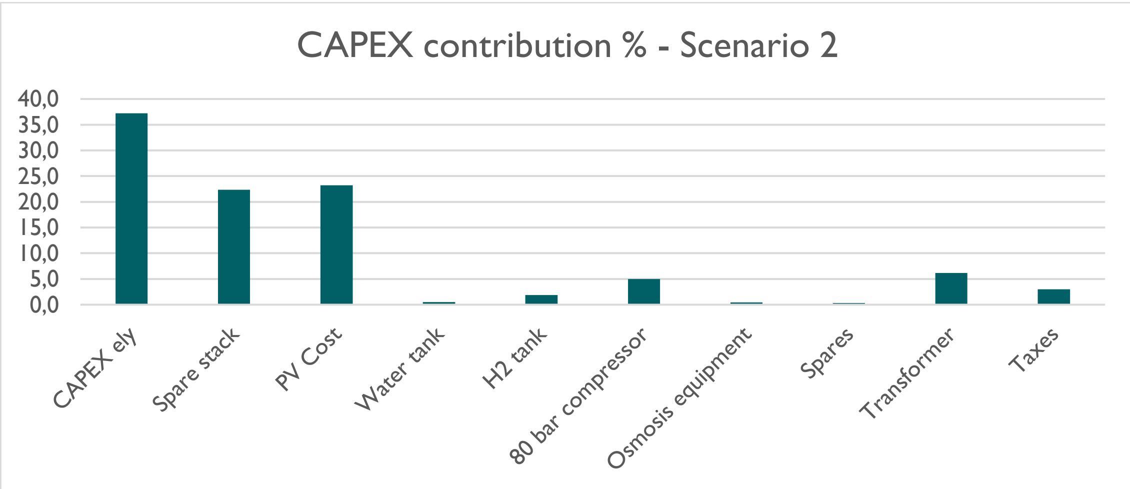


FIGURE 12. CAPEX CONTRIBUTION RATE IN SCENARIO 2

RESULTS OF SCENARIO 3: POWERED BY PPA + 7.5 MW OF PHOTOVOLTAIC WITH FULL PRODUCTION

TABLE 9. RESULTS OF SCENARIO 3 (PPA+PV) 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 H_2**

The same considerations of scenario 2 have been taken for the calculation of these parameters.

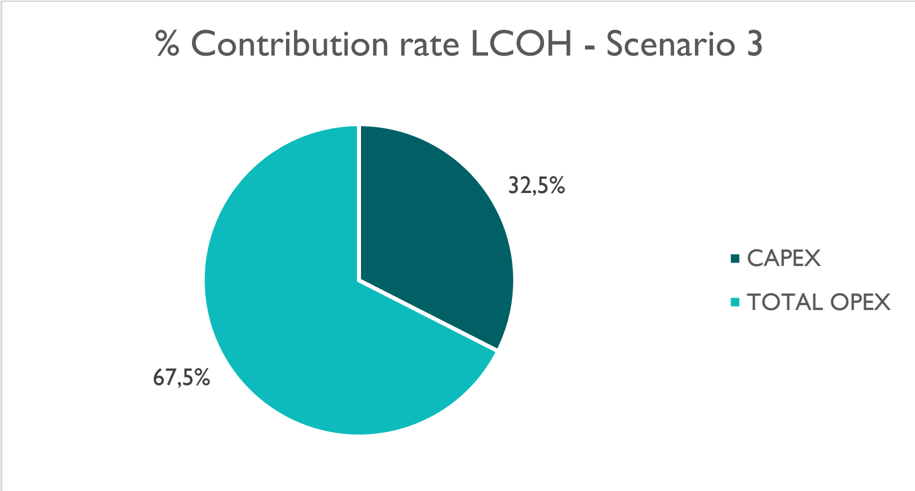


FIGURE 13. RATE CONTRIBUTION RATE OF SCENARIO 3

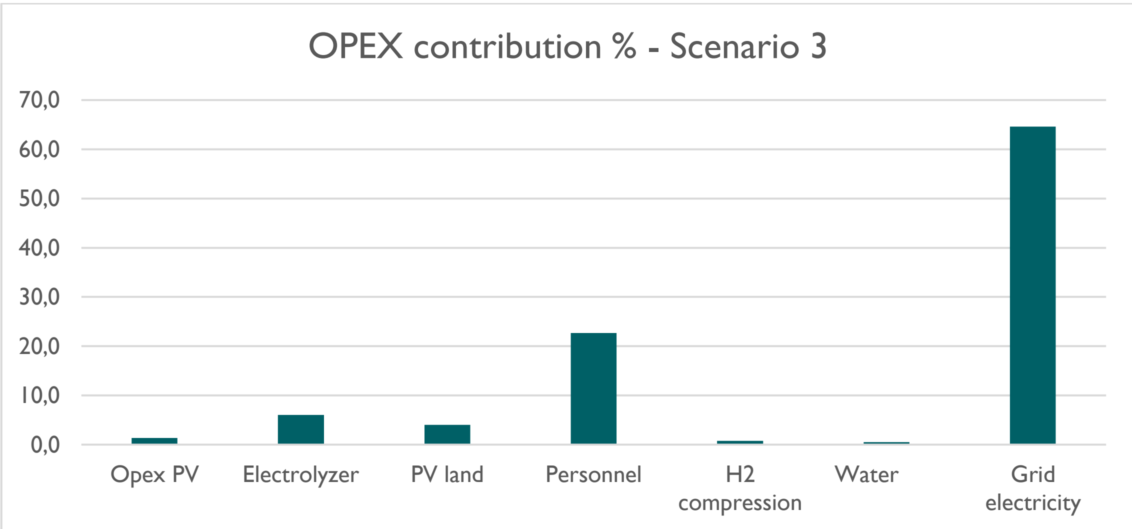


FIGURE 14. OPEX CONTRIBUTION RATE IN SCENARIO 3

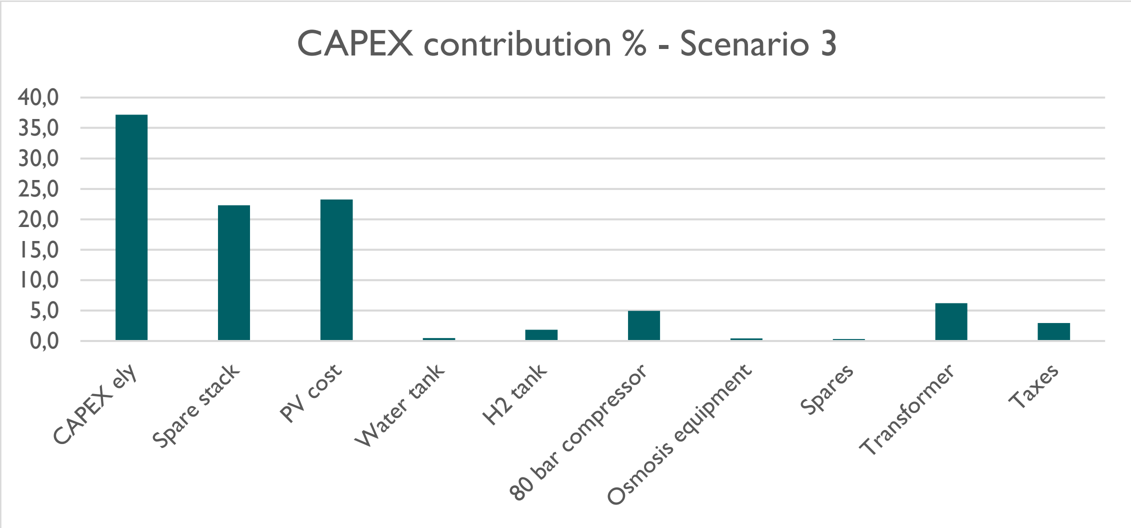


FIGURE 15. CAPEX CONTRIBUTION RATE IN SCENARIO 3

GENERAL RESULTS

TABLE 10. GENERAL RESULTS FOR ALL SCENARIOS

	Results Scenario 1	Results Scenario 2	Results Scenario 3
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**

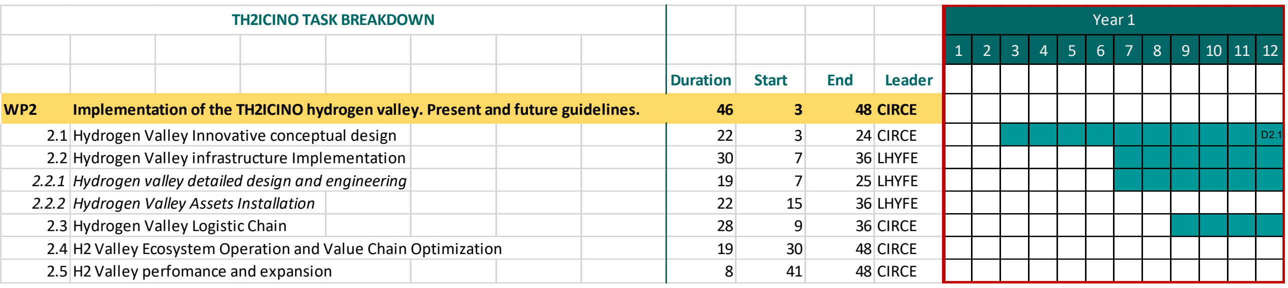
As can be seen in Table 10, the LCOH price goes from higher to lower depending on the scenario. Make sense that the lowest price be in scenario 3, as this is where we produce the most hydrogen making the cost cheaper.

CONCLUSIONS

This mid-term deliverable establishes the base of description and calculation of the operation of the planned TH2ICINO facility, describing until three scenarios comparing the main parameters through a developed tool. Each scenario is adapted to TH2ICINO performance and consumptions requirements reducing LCOH.

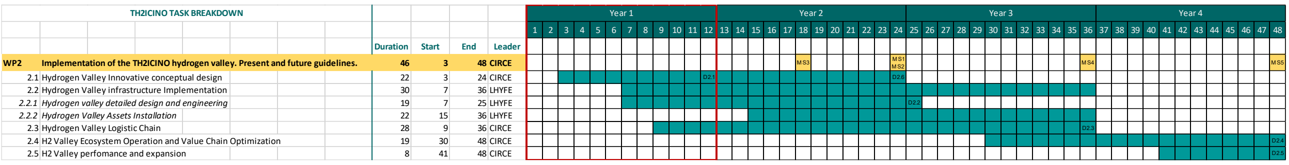
DEVIATIONS

No deviations found



TH2ICINO TASK BREAKDOWN		Duration	Start	End	Leader
WP2	**Implementation of the TH2ICINO hydrogen valley. Present and future guidelines.**	**46**	**3**	**48**	**CIRCE**
2.1	Hydrogen Valley Innovative conceptual design	22	3	24	CIRCE
2.2	Hydrogen Valley infrastructure Implementation	30	7	36	LHYFE
2.2.1	*Hydrogen valley detailed design and engineering*	19	7	25	LHYFE
2.2.2	*Hydrogen Valley Assets Installation*	22	15	36	LHYFE
2.3	Hydrogen Valley Logistic Chain	28	9	36	CIRCE
2.4	H2 Valley Ecosystem Operation and Value Chain Optimization	19	30	48	CIRCE
2.5	H2 Valley perfomance and expansion	8	41	48	CIRCE

FIGURE 16: TH2ICINO GANTT FOR WP2 (YEAR 1).



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2.5	H2 Valley perfomance and expansion	8	41	48	CIRCE

FIGURE 17: TH2ICINO GANTT FOR WP2 (PROJECT).

OBSTACLES

TECHNOLOGY

1. Market difficulties (high price of H2 respect to other fuels/sources 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

Task ongoing until M24 (August 2025).

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