Green hydrogen valleys: a preliminary case study for the industrial area of Ravenna

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Abstract: In November 2020 Italian government released two drafts concerning a research and innovation roadmap and a national strategy about green hydrogen. A general target of 2% for the green hydrogen penetration in the Italian energy market is foreseen by 2030, corresponding to 0.7 million tons of green hydrogen production per year. Since no green hydrogen plants exist at industrial scale in Italy, a challenging strategy is necessary to achieve the expected target. To date, investors are discouraged from entering the market due to the existing barriers. However, applying and replicating the so-called "hydrogen valleys" concept represents a possible way to approach the short-medium term green hydrogen strategy. Since they are "*regional ecosystems […] developed relying on local production of hydrogen based on decentralized renewable energy production and local demand, transported over short distances*", new hydrogen valley projects would be characterized by lower and decentralized production as well as reduced transportation costs, thus potentially representing a more attractive investment. However, the techno-economic attractiveness of the project has to be assessed to justify the investment. Therefore, the paper describes a preliminary case study for a green hydrogen valley located in the industrial area of Ravenna. After a short introduction of the hydrogen valley concept, the paper shows the obtained results for a scenario-based techno-economic analysis concerning the realization of a hydrogen valley in the industrial area of Ravenna.

Keywords: Green Hydrogen, Green Hydrogen Valleys, Hydrogen Plants, Renewable Energy Sources

1.Introduction

Green hydrogen, i.e., the hydrogen produced from renewable sources, is essential on the path to a net-zero greenhouse gas emission future (Kakoulaki et al., 2021). Specific actions are needed to satisfy the long-term hydrogen roadmap designed by the European Commission (Commissione Europea, 2020), which includes:

- for 2020-2024: electrolyzer capacity is expected to be scaled up to 6 GW, i.e., a capacity able to produce up to 1 million tons of green hydrogen per year;
- for 2025-2030: the electrolyzers capacity's target is increased up to 40 GW, ensuring the production of up to 10 million tons per year;
- for 2030-2050: green hydrogen technologies should be wholly deployed in all the hard-to-decarbonize sectors.

Following the European strategy, the Italian government designed a national target for electrolyzers' capacity up to 5 GW by 2030 (MISE, 2020), i.e., 12.5% of the European one. All energy-consuming sectors (industry, transport, building) have to contribute to achieving the ambitious goal. In the first phase, green hydrogen solutions should be implemented where hydrogen demand already exists, such as, for example, in petroleum processing, petrochemical production, oil and fat hydrogenation, fertilizer production, metallurgical applications, electronics industry (Ramachandran & Menon, 1998). At the same time, green hydrogen can be used in substitution of traditional fossil fuels also in energy-intensive and hard-to-abate sectors, such as heavy transport sectors (i.e., for truck, trains, or ships) (Herwartz et al., 2021; Mauzerall et al., 2021; Ortiz et al., 2021) or productive processes (i.e., steel, glass, ceramic sectors) (Bailera et al., 2021; Hammond et al.., 2021; Kandili et al., 2015; Zier et al., 2021)

However, several barriers still hinder green hydrogen potential in Italy (Saccani et al., 2020). Barriers like i) investment and operative costs, ii) hydrogen transport and distribution, iii) permit procedures, iv) safety and social concerns are complex to be managed by single companies. Therefore, the realization of green hydrogen clusters, the so-called "Hydrogen Valleys", is crucial to stimulate in the early phase synergies and collaboration of more actors involved in green hydrogen production and consumption within a specific geographical area.

The Hydrogen Valley concept was introduced only a few years ago. So a small number of projects is ongoing, as reported by the Hydrogen Valley Platform, a freely accessible database that collects information and data regarding existing projects (Weichenhain et al., 2021). 31 projects in 17 Countries were recorded in the platform, as shown in Figure 1 and Table 1A in the Appendix. As shown in the table, only four projects are currently in operation. In contrast, the remaining ones are planned to be fully implemented by 2035, reaching an expected investment greater than 23 billion euros worldwide. About the four in operation, two electrolyzers with a total installed capacity equal to 1.5 MW produce up to 50 ton/year of green hydrogen converted back into heat and power for buildings and vessels or supplied to local refueling stations in the BIG HIT project (UK). In the HYBALANCE project (DK), a 1.2 MW electrolyzer produced 120 tons of green hydrogen from June 2018 to August 2020 supplied to the mobility and the industrial sectors. The Phi Suea House Project (TLD) was the first solar-hydrogen project in which a 2 Nm^3/h electrolyzer was integrated into an off-grid multi-house. Finally, in the Hydrogen Valley South Tyrol project (IT), water electrolyzers produce hydrogen for the mobility sector.

Figure 1. Hydrogen valleys' projects in the world. Only 4 out of 32 have been completed and are into operation (H2 Valley, 2020).

However, the green hydrogen production costs are still higher than the state-of-the-art hydrogen production costs via fossil fuel reforming (Dincer & Acar, 2015) to justify installing new plants. For example, (IEA, 2021) reports a hydrogen production cost between 0.9-3.2 $/kg for steam methane reforming while (Christensen 2020) calculated a medium price for hydrogen production in Europe equal to 13.11 $/kg, 19.23 $/kg, and 10.85 $/kg respectively for electrolyzers i) connected to the electric grid, ii) directly connected to a renewable electricity generator or iii) operated with electricity otherwise curtailed.

Although investments in renewable energy production capacities are expected to be in the range of 180-470 billion euros in Europe in the next thirty years (Commissione Europea, 2020), the feasibility of Hydrogen Valleys' projects must be carefully assessed. Therefore, the paper aims to preliminary investigate the feasibility of a green hydrogen valley located in a city of Northern Italy, i.e., Ravenna (44.4184° N, 12.2035° E). For this purpose, the second chapter describes the methodology, while the third one discusses the preliminary results.

2.Methodology

To preliminary evaluate the techno-economic feasibility of the proposed solution, different steps were performed as described in the subsections.

2.1 Hydrogen Valley potential analysis

First of all, the green hydrogen potential in the investigated area was characterized. The following data were analyzed:

- hydrogen consumption: the industrial companies active in the area were contacted and interviewed to assess if hydrogen demand exists. Notably, specific questions were asked, such as:
    - the total annual hydrogen demand G_{H2} in [Nm^3/y];
    - how hydrogen is currently supplied.
- Hydrogen production in the area: the database "*Environmental Assessments and Authorizations: SEA-EIA-IPPC Permit*", managed by the Italian Ministry of the Environment, was used as the primary source of information. The following data about local hydrogen producers were identified:
    - the total annual production in [Nm^3/y];
    - how hydrogen is currently produced.

2.2 Identification of scenarios

The paper investigates different scenarios. These scenarios are the result of the combination of two main parameters:

- the fraction of green hydrogen, f_w [%]: the preliminary analysis includes three different targets, i.e., 1%, 5%, and 10% of the current consumption.
- The electricity source: two options are considered. Electrolyzers can be supplied only by the grid through certified renewable energy or by locally installed renewable plants and by the grid when renewable plant production is insufficient. In this study, only photovoltaic (PV) plants are considered for local renewable power production.

Table 1 resumes the six scenarios (Ss) investigated for the specific context of Ravenna. The six scenarios were defined to preliminary investigate the impact of main strategic assumptions; therefore, further analysis will be needed to identify the optimal solution in terms of economic and environmental impacts.

Table 1. Investigated scenarios for Ravenna Hydrogen Valley.

Electricity source	**Fraction of produced green hydrogen f_w**		
	1%	**5%**	**10%**
100% certified green energy	S1	S2	S3
100% local solar renewable energy or certified green energy when renewable energy is not sufficient	S4	S5	S6

2.3 The green hydrogen plant configuration and design

Due to the preliminary stage of the analysis, the detailed design of the green hydrogen plant is not in the scope of the following assessment. The simplified green hydrogen plant configuration is shown in Figure 2.

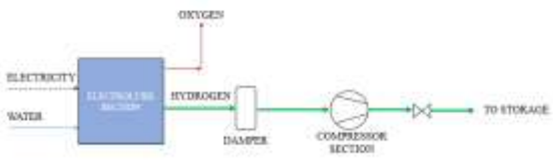

Figure 2. The simplified green hydrogen plant configuration.

Green hydrogen is produced in the electrolysis section. Alkaline technology was assumed for the purpose. However, the methodology does not change in the case of implementation of other technologies such as Proton Exchange Membrane (PEM), Anion Exchange Membrane (AEM), or Solid Oxide one (SOEC). Electrolyzers' nominal capacity P_{WH} [kW] is calculated by Eq. (1):

$$P_{WH} = (G_{GH2} \times \rho \times LHV/(T \times 3600))/\eta_{WH} \quad (1)$$

Where G_{GH2} is the green hydrogen demand [Nm^3/y], ρ is hydrogen density [kg/Nm^3] (=0.0889 kg/Nm^3), LHV is hydrogen Low Heating Value [kJ/kg] (=120.000 kJ/kg), T is the number of annual working hours [h], and η_{WH} is electrolyzers' efficiency [%]. In the assessment, electrolyzers' efficiency is assumed to equal 70%, according to the range reported in (Guzzini et al., 2020). T is considered equal to 8000 h/year. Since the existing demand is known, the green hydrogen amount G_{GH2} [Nm^3/y] is calculated by Eq. (2):

$$G_{GH2} = G_{H2} \times f_w \quad (2)$$

Downstream from the electrolysis section, a compression section ensures the required hydrogen storage pressures in the existing facilities. The installed electrical capacity P_C [kW] is calculated by Eq. (3):

$$P_C = [G_{GH2}/(T \times 3600)] \times \rho \times L_R \quad (3)$$

where L_R is the real electrical compression work of hydrogen compressors [kJ/kg]. Pressures of 10 bar and 200 bar are assumed, respectively, upstream and downstream the compression section. L_R is computed by Eq. (4):

$$L_R = L_I/(\eta_{is} \times \eta_m \times \eta_{aux} \times \eta_{el}) \quad (4)$$

Where L_I is the isentropic work [kJ/kg], η_{is} is the isentropic efficiency (=70%), η_m is the mechanical efficiency (=95%), η_{aux} is the auxiliary efficiency (=96%), and η_{el} is the electrical efficiency (=95%). Since an isentropic compression work equal to 5370 kJ/kg results in the reported operative conditions, a value equal to 8850 kJ/kg is computed for real compression work L_r.

The size of the damper, i.e., the small storage volume installed between the production and compression sections to take into account the possible different nominal flowrates of the two main components, is not calculated in the paper since its role is assumed negligible in the assessment.

2.4 The design of the local renewable plant

While the purchasing of certified renewable energy characterizes scenarios S1, S2, and S3 from the grid, scenarios S4, S5, and S6 include the local production of renewable energy through floating PV panels. The renewable plant is sized aiming to supply all the necessary power to the electrolyzers. The nominal capacity of the PV plant, P_{ren} [kW], is designed to supply all the annual electricity consumption of the green hydrogen plant. For this purpose, the data of Ravenna daily solar radiation was taken by Solar Atlas Database (ESMAP, 2019). By following this criterion, even if the annual energy balance is zero, surplus production of electricity from renewable is expected in some period of the year, i.e., in the summer. In contrast, in other periods, i.e., in winter or during the night, the electricity is purchased from the grid as certified renewable energy. Furthermore, in scenarios S4, S5, and S6, the hypothesis is that the instantaneous surplus produced by the plants is locally self-consumed.

2.5 Economic assessment: Levelized cost of hydrogen

The Levelized Cost of Hydrogen (LCH) method was considered (Maggio et al., 2020) to compare the six scenarios previously defined. LCH is calculated by Eq. (6):

$$LCH = \frac{CAPEX + \sum_{n=1}^{N} \frac{Opex_n}{(1+r)^n}}{\sum_{n=1}^{N} \frac{G_{GH2} \times \rho \times (1-SDR)^n}{(1+r)^n}} \quad (6)$$

where CAPEX are the Capital Expenditures [€], OPEX are the Operative Expenditures [€], r is the discount rate [%], n is the year, N is the expected plant life [year], and SDR is the plant degradation rate [%].

The CAPEX [€/y] are calculated by Eq. (7):

$$CAPEX = (P_{WH+C} \times C_{WH} + P_C \times C_C + P_{ren} \times C_{ren}) \times SF \quad (7)$$

C_{WH}, C_C, and C_{ren} are respectively the specific cost of the electrolyzers, compressors, and floating PV plant sections [€/kW]. References were taken respectively from (Proost 2019), (FCHJU, 2017), and (Martins, 2012). SF is a safety factor to consider the design, the permit procedures, and the realization of the civil works.

The OPEX [€/y] are calculated by Eq. (8):

$$OPEX = (P_{WH} + P_C) \times T \times (C_{EL} + C_{CO}) + CAPEX \times f_M \quad (8)$$

where C_{EL} is the purchase cost of the electricity from the grid [€/MWh], C_{CO} is the cost of a Certificates of Origin [€/MWh], and f_M is a factor that takes into account the annual maintenance required by the whole plant in accordance to (FCHJU, 2017) and (Merlet, 2018). Since C_{CO} is determined every three months by auction, and it is not constant, the average cost of the period 2017-2019 was considered in the assessment. Even if the global energy balance is zero in scenarios S4, S5, and S6, the same is not from an economic point of view. However, due to the value of C_{CO}, the economic impact is assumed negligible in this preliminary analysis. Table 2 summarizes the values used in the study.

Table 2. Assumed values for the economic analysis.

	Value	**Unit**
Safety factor (SF)	20	%
Discount rate (r)	4.8	%
Degradation rate (SDR)	1	%/y
Expected plant life (N)	20	years
Maintenance factor (f_M)	3	%
Electricity cost (C_{EL})	100.87	€/MWh
Certificates of Origin cost(C_{CO})	0.88	€/MWh

2.6 Environmental assessment

The replacement of grey hydrogen, i.e., the hydrogen produced by fossil fuel, with green hydrogen ensures a reduction of greenhouse gas (GHGs) into the atmosphere. The total amount of annual equivalent emitted CO_2 (G_{CO2}) emitted in the atmosphere is calculated by Eq. (9):

$$G_{CO2} = G_{H2} \times f_{CO2,H2} + E_S \times f_{CO2,EL} \quad (9)$$

$f_{CO2,H2}$, and $f_{CO2,EL}$ are the carbon dioxide emission factors respectively for producing 1 Nm^3 of grey hydrogen [ton_{CO2}/Nm^3_{H2}] and 1 MWh of electricity by the national generation system [ton_{CO2}/MWh]. E_s is the surplus energy produced by the PV plant in the period self-consumed by the company [MWh/year]. Particularly Eq. (9) considers that less electricity is purchased by the company from the national grid when an energy surplus occurs. Therefore, since no PV plant was considered in S1, S2, and S3, the second member of Eq. (9) is simply zero in these scenarios. The values used in the analysis are reported in Table 3.

Table 3. Assumed values for the environmental analysis.

Parameters	Value	Unit
$f_{CO2,H2}$ (MATTM, 2021)	9.6×10^{-4}	$tonCO_2/Nm^3_{H2}$
$f_{CO2,EL}$, (ISPRA, 2019)	0.2848	$tonCO_2/MWh$

To compare the environmental and economic benefit resulting from the green hydrogen plant, an annual carbon dioxide removal cost C_{CO2} [€/ton_{CO2}] is calculated by Eq. (10):

$$C_{CO2} = G_{GH2} \times \rho \times (LCH - LCH_0)/(G_{CO2}) \qquad (10)$$

LCH_0 is the hydrogen production cost of the baseline scenario that was assumed equal to 2.7 [€/kg].

3.Results and discussion

3.1 Hydrogen Valley potential in Ravenna

Two active companies currently consume hydrogen in the industrial area of Ravenna, close to the port, at the left of the Canal Corsini (encircled in red in Figure 3). For confidentiality reasons, these companies are called “Consumer 1” and “Consumer 2”. In addition, two hydrogen production companies were found. Also, in this case, the terms “Producer 1” and “Producer 2” are used.

Figure 3. The investigated industrial area in Ravenna.

Data about hydrogen consumption and production are reported respectively in Table 4 and Table 5. Particularly, the annual hydrogen demand is equal to 36,700,000 Nm^3/y (= 3,263 ton/y equivalent to 391,516 GWh/year). The whole local demand is currently covered by Producer 1 and transported through the area in a dedicated hydrogen network. Methane steam reforming plants are operated by the two Producers to produce hydrogen. As shown in Table 4, up to 45,000,000 Nm^3/y of hydrogen are annually produced, resulting in a methane consumption equal to almost 21,045,000 Nm^3/y.

Table 4. End-users available data.

Parameters	End-user 1	End-user 2
Annual demand, [Nm^3/y]	4,700,000	32,000,000
Supply	From a local producer	From a local producer

Table 5. Hydrogen producers’ available data.

Parameters	Producer 1	Producer 2
Annual nominal production, [Nm^3/y]	40,000,000	5,000,000
Specific methane consumption [Nm^3/Nm^3]	0.457	0.553

3.2 Scenario analysis: the size of the plants and energy consumption

Almost 1,164 kWh/kWp can be produced yearly by a floating large-scale PV plant installed in the area of Ravenna. As shown in Figure 4, PV energy production reaches the maximum in the summer period (i.e., 0.631 kWh/kWp), while a drastic reduction occurs during the winter months.

Figure 4. The monthly average hourly profile for a photovoltaic plant in Ravenna (kWh/kWp)

The calculated PV plant size is reported in Table 5 for the six scenarios. No PV plant is considered for scenarios S1, S2, and S3 since the grid covers all the electricity demand. For S4, i.e., a green hydrogen penetration of the 1%, a floating PV plant of 1.5 MW, i.e., ≈1.600 MWh/year, is necessary, resulting in an occupied area equal to 17.500 m^2, i.e., 12.5 m^2/kWp in accordance to the Alqueva Floating Photovoltaic project (World Bank, 2019). The size of the floating PV plant achieves the nominal capacity of 14 MW, i.e., ≈16.400 MWh, to ensure a 10% penetration of green hydrogen in S6, and up to 175.500 m^2 of surface are needed.

Table 6. Size of the plants for each scenario considered.

Scenario	G_{GH2} [Nm^3/y]	P_{WH}, [kW]	P_{ren}, [kWp]	Area, [m^2]
S1	367.000	195	/	/
S2	1.835.000	970	/	/
S3	3.670.000	1.950	/	/
S4	367.000	195	1.500	17.500
S5	1.835.000	970	7.000	87.700
S6	3.670.000	1.950	14.000	175.500

In Figure 5 the areas occupied by the floating PV plants are shown in comparison with the aerial view taken from Google Earth. As shown, many areas, like swamps, could be recovered to install the floating PV panels reducing the potential technical and economic efforts required for an offshore installation. However, no investigations were done about any possible issues to realize the PV plant in the area in this stage such as permit or land use limitations.

Figure 5. The size of the floating photovoltaic panels in scenarios S4, S5, and S6.

Concerning the energy assessment, up to 1.6, 8.2, and 16.3 GWh/y are supplied to the green hydrogen plant in scenarios S1-S4, S2-S5, and S3-S6. As shown in Table 6, as defined in the method to size the renewable plant, the annual renewable energy produced in scenarios S4, S5 and S6 are the same that the green hydrogen plant consumes.

Table 7. Energy assessment for each scenario assessed.

Scenario	E_{WH+C}, [MWh/y]	E_{ren}, [MWh/y]
S1	1.634	0
S2	8.170	0
S3	16.339	0
S4	1.634	1.634
S5	8.170	8.170
S6	16.339	16.339

3.3 Economic and environmental assessment

Different economic investments depending on the selected scenario are calculated, as shown in Table 7. The greatest fraction of the investment for scenarios S1, S2, and S3 is due to electrolyzers. In contrast, for scenarios S4, S5 and S6, the floating PV plant represents, respectively, 76%, 88%, and 89% of the total investment (Figure 6) since the net electricity consumption are zero in scenarios S4, S5, and S6, lower OPEX result respect to scenario S1, S2, and S3.

Table 7. Calculated CAPEX and OPEX for different scenarios.

Scenario	CAPEX, [€]	OPEX, [€]
S1	537.700	182.000
S2	1.139.500	865.000
S3	2.075.000	1.720.000
S4	2.220.000	67.000
S5	9.560.000	287.000
S6	18.920.000	568.000

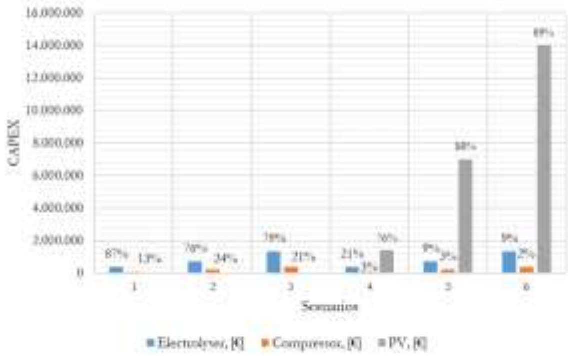

Figure 6. Analysis of the CAPEX focusing on electrolyzers, compressors, and photovoltaic plant.

About the LHC, S3 is the best economic scenario with 6.2 €/kg (Figure 7). According to the ranges reported by the Hydrogen Valley projects’ database, the value is lower than that reported by (Christiansen 2020). Slightly higher values are obtained for scenarios S4, S5, and S6. Therefore, to date, the connection of the electrolyzers to the grid instead of local renewable plants appears more convenient from an economic point of view. Nevertheless, by focusing on the best scenario (S3), the production of green hydrogen is still less profitable than grey hydrogen. Even by reducing the purchase cost of the electricity by 50%, the green hydrogen production cost would result equal to 3.5 €/kg.

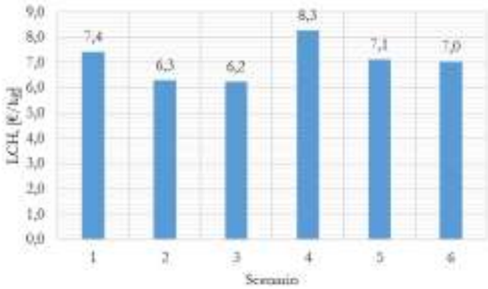

Figure 7. LCH for the six scenarios.

Concerning the CO_2 avoided emission, S6 has the most significant impact with almost 8.000 ton/y avoided, as shown in Figure 8. Practically 15.5 GWh/year are self-consumed in S6, replacing electricity produced by the national energy system. Due to the smaller size of the PV plant, a lower annual energy surplus results for scenarios S4 (1.0 MWh/year) and S5 (7.3 MWh/year).

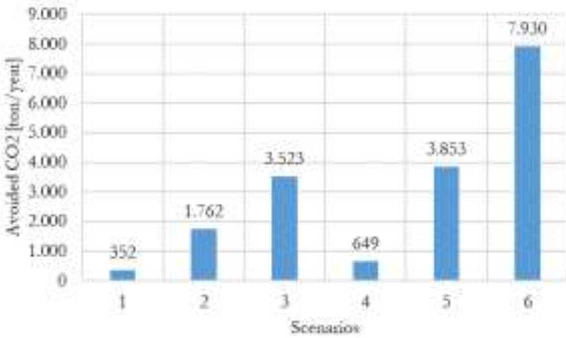

Figure 8. Avoided CO2 for the six scenarios.

As shown in Table 8, the annual carbon dioxide removal cost for all scenarios is still more significant than the value recognized to CO_2 in 2021 (SENDECO, 2021), i.e., 36

€/ton. Therefore, despite the environmental benefit, the removal cost of CO_2 is still too high to justify the installation of a green hydrogen plant in the specific case study.

Table 8. Calculated CAPEX and OPEX for different scenarios.

Scenario	C_{CO2}, [€/ton]
S1	436
S2	334
S3	328
S4	279
S5	187
S6	178

4. Conclusions

The industrial area of Ravenna is a good option for the implementation of the hydrogen valley concept since hydrogen demand and production are already present. Consequently, permit procedures and technical and safety challenges like, for example, but not limited to, hydrogen transportation and distribution, will not represent barriers for any interested possible investors.

The paper analyzed six different scenarios as a combination of growing green hydrogen penetration rate and different renewable power supplying strategies to preliminary assess the technical and economic feasibility of the Hydrogen Valley concept in Ravenna. The best techno-economic solution is currently the one that foresees the highest penetration rate evaluated (10%) and the connection to the grid. However, these preliminary results show that despite the technical feasibility of the proposed solutions, economic sustainability is far from being achievable in all the considered scenarios. No investigated scenario is competitive if compared with the current cost of hydrogen production via steam reforming of methane. Furthermore, the environmental benefits related to CO2 emission reduction do not justify the investment, even if it was found that the scale factor, i.e., the increase of green hydrogen penetration rate in the area, could produce benefits. Other options will be investigated in the future. For example, the installation of offshore wind turbines in replacement to PV plants and the operation of an off-grid green hydrogen plant integrated with an annual hydrogen storage facility to not purchase electricity from the grid will be assessed. Furthermore, a sensitivity analysis will be proposed to complete the analysis and to give indications to the local interested stakeholders.

But it is anyway evident that the design optimization alone will not be sufficient to reduce the production cost down to competitive market values. Therefore, together with the development of the strategy, it is fundamental to design financial instruments to support the adoption of green hydrogen in local clusters. Therefore, policymakers and stakeholders should identify the green hydrogen national strategy and the economic mechanisms to stimulate investors. First of all, policies could reward green hydrogen plants’ operation for grid balancing service to avoid congestion produced by unpredictable power dispatching from PV and wind power plants. Moreover, specific financing support that covers a certain fraction of the initial investment through grants or subsidies is essential for the success of the green hydrogen business. Finally, a tailored carbon dioxide tax for some specific hydrogen-consuming sectors, including an increasing trend planned over the next decades, could favor the transition to sustainable generation and use of hydrogen. Combining the instruments above could enhance the short-medium transition to Hydrogen Valleys of industrial clusters in which hydrogen is already produced and consumed.

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Appendix A. FIRST APPENDIX

Table 8. Hydrogen valley's projects.

Project	Investment [M€]	Country	H_2 production [ton/day]	Status
Advanced Clean Energy Storage Project	1000	USA	100	1
BIG HIT (Building Innovative Green Hydrogen Systems in Isolated Territories)	13.50	UK	N.A.	2
Black Horse	5800	SK	320	3
CEOG (Centrale Electrique de l'Ouest Guyanais)	121	GUF	2	4
Crystal Brook Hydrogen Superhub	370	AUS	25	3
eFarm	16	DE	0,6	5
Eyre Peninsula Gateway	150	AUS	35	5
FH2R	N.A.	JP	0,5	
Foshan Nanhai Xianhu Lake Hydrogen Valley Town	N.A.	PRC	N.A.	5
Green Crane (Western route)	1470	ES	80	4
Green Hydrogen @ Blue Danube	N.A.	RO	220	3
Green Hysland	30	ES	1	4
Green Octopus	9700	NL	800	3
H2Rivers	52,2	DE	N.A.	5
HEAVENN	88	NL	7,7	5
Hy-Fi (Hydrogen Facility Initiative)	N.A.	CL	650	3
HyBalance	15	DK	N.A.	2
HyBayern	45,08	DE	1,18	4
Hydrogen Delta	N.A.	NL	140	4
Hydrogen Valley South Tyrol	55	IT	1	5
HyNet North West	4000	UK	2160	4
HyWays for Future	90	DE	3	3
NDRL (Norddeutsches Reallabor - Living Lab Northern Germany)	325	DE	10	4
Normandy Hydrogen	N.A.	FR	N.A.	5
Phi Suea House Project	N.A.	TH	N.A.	2
Port of Los Angeles Shore to Store Demonstration Project	70	USA	N.A.	5
Regional Hydrogen Roadmap	N.A.	FR	N.A.	5
Rugao Hydrogen Energy Town	N.A.	PRC	N.A.	2
WIVA P&G (Wasserstoffinitiative Vorzeigeregion Austria Power & Gas)	79	AUT	10	5
ZEV - Zero Emission Valley	70	FR	1,6	5
Zhangjiakou demonstration project	N.A.	PRC	N.A.	5

Note:
The status of the project is in accordance with the following symbol: 1) Initial funding received, 2) Fully implemented, 3) High level plan on government level exists, 4) Concrete project plan agreed by main stakeholders, 5) Start of implementation. Not available information is reported as NA.