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ENEA's hydrogen demo valley: forecasting the economic, urban, social and environmental impact of a hydrogen-based experimentation ecosystem

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Introduction

Numerous signals indicate the urgency of a change of direction in the world energy systems[1]. The steady increase in energy needs due to the industrialization of emerging economies[2], the approaching peak of fossil fuel production[3] and growing carbon dioxide emissions[4] pose a significant risk to maintaining the conditions necessary for the survival of the human species[5]. Faced with these considerations, the scientific community[6] is mobilizing to explore all alternative energy sources that are both renewable and characterized by low cost of production. In this scenario, hydrogen is receiving considerable attention[7] in terms of activation of funding channels and publication of European and national frameworks[8] to integrate appropriate technologies. Nevertheless, there are many grey areas related to its production: European and national regulations are often in disagreement about which parameters[9] must be met for the hydrogen in question to be considered sustainable. Moreover, the efforts directed to the development differ significantly from country to country[10]. Based on the EU Sustainable Finance Taxonomy proposal for a Delegated Act, the European legislator seems determined to grant the qualification of 'sustainable', and therefore fundable, to energy production plants based on the exploitation of fossil gas[11]. This provision aligns with the European Commission's desire to set more permissive limits on the maximum amount of C02 emitted during hydrogen production[12]. The tangible result of these provisions is that soon it will seem paradoxically convenient to channel investments towards the

[1] J. Rifkin, Economia all'Idrogeno, Mondadori, 2003, ed 1.

[2] Hove, S., & Tursoy, T. (2019). An investigation of the environmental Kuznets curve in emerging economies. *Journal of Cleaner Production*, *236*, 117628.

[3] BP. BP annual report. British petrolleum. https://www.bp.com/ content/dam/bp-country/fr_ch/PDF/BP_Annual_Report_and_ Form_20F_2014.pdf. Published 2014.

[4] NASA Climate Change And Global Warning, https://climate.nasa.gov/causes/.

[5] Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855.

[6] Fermin Cuevas, Junxian Zhang, Michel Latroche. The vision of France, Germany, and the European Union on future hydrogen energy research and innovation. Engineering, Elsevier, 2021, 7 (6), pp.715- 718. 10.1016/j.eng.2021.04.010 .

[7] Kovač, A., Paranos, M., & Marciuš, D. (2021). Hydrogen in energy transition: A review. *International Journal of Hydrogen Energy*, *46*(16), 10016-10035.

[8] Lebrouhi, B. E., Djoupo, J. J., Lamrani, B., Benabdelaziz, K., & Kousksou, T. (2022). Global hydrogen development-A technological and geopolitical overview. *International Journal of Hydrogen Energy*.

[9] Europa, B. (2022). Leaked Taxonomy Proposal: Fossil gas "Sustainable" label relies on promises in bad faith – still risks wasting all our renewable energy - Bellona.org. Retrieved 19 April 2022, from https://bellona.org/news/renewable-energy/2022-01-leaked-taxonomy-proposal-fossil-gas-sustainable-label-relies-on-promises-in-bad-faith-still-risks-wasting-all-our-renewable-energy

[10] Council, H. (2020). Path to hydrogen competitiveness: a cost perspective.

[11] Europa, B. (2022). Leaked Taxonomy Proposal: Fossil gas "Sustainable" label relies on promises in bad faith – still risks wasting all our renewable energy - Bellona.org. Retrieved 19 April 2022, from https://bellona.org/news/renewable-energy/2022-01-leaked-taxonomy-proposal-fossil-gas-sustainable-label-relies-on-promises-in-bad-faith-still-risks-wasting-all-our-renewable-energy

[12] Tassonomia UE più 'permissiva' sull'idrogeno: limite di CO2 fissato a 3 Kg per ogni Kg di H2 prodotto - HydroNews. (2022). Retrieved 19 April 2022, from https://hydronews.it/tassonomia-ue-piu-permissiva-sullidrogeno-limite-di-co2-fissato-a-3-kg-per-ogni-kg-di-h2-prodotto/

development of hydrogen production technologies that are not at all consistent with the urgencies described at the beginning of this paragraph. As pointed out above, the European Union's behavior does not seem to be in line with that of the respective national authorities[13]. On the other hand, the latter, although mature enough to structure their hydrogen roadmaps in a spirit more genuinely aimed at the value of sustainability, lack alignment with each other[14]. As emphasized by the Hydrogen Council, coordination and standardization factors are vital to pursue and achieve tangible results consistently[15]. In particular, the Council suggests that member states should jointly structure legal and economic frameworks to break down any possible barriers to cross-border collaboration and investments and provide infrastructures that both local and foreign players can use. Therefore, this thesis aims to analyze the activity carried out by ENEA, the Italian national agency responsible for the development of new technologies, regarding the Hydrogen demo valley project, which, once functional, will constitute an ecosystem of experimentation to encourage the development and optimization of the most promising technologies related to the advancements in the subject of hydrogen. It will thus be investigated whether such energy carrier may effectively represent a solution to societal issues deep-seated in the Italian national context. In this sense, the author chose to perform a SROI (Social Return On Investments) analysis on the aforementioned demo valley, which will be focused on four precise aspects: economic, environmental, social and urban. As the project commissioned by ENEA constitutes the first example of Hydrogen Valley in Italy, in fact, it serves as the ideal testbed to understand to what extent hydrogen can positively affect the above mentioned four dimensions.

Research structure

The study has been organized into five main chapters. The first chapter introduces the research, presenting the background, the research problem, the purpose and the work's limitations. The second chapter is constituted by the literature review of previous research, which provides a basis to support the empirical findings and introduces the reader to the research question. The third chapter concerns the methodology used for the research. It will go through the choice of the research strategy, the research method, the research design and the criteria for data collection and analysis. After having provided the reader with a better understanding of the scope of this thesis, the fourth chapter will be employed for the presentation of the case study. Chapter five will instead focus on the impact assessment related to the case study itself.

Limitations

Although this thesis has been elaborated to constitute a complete document as possible, several difficulties have been encountered during its drafting. The case study, for instance, has been selected due to its undeniable relevance; however, it still consists of a not yet fully launched project. Even by having at disposal a satisfying number of sources concerning its aims and scopes, it has not been possible to form objectively correct

[13] Council, H. (2020). Path to hydrogen competitiveness: a cost perspective.
[14] Ibid.
[15] Ibid.

statements circa the technologies and activities contextually conducted, but only suppositions. Equally, given the impossibility of empirically observing the project's direct effects on its surroundings, the considerations related to the SROI analysis are also theoretical. It should also be underlined that the sources employed to draft this document have been predominantly provided by ENEA, so that the Authority responsible for the management of the project itself. Although there is no reason to doubt the latter's honesty, the reader's attention should still be brought to the lack of third parties' reflections on the topic. Additionally, it is necessary to highlight that other documents that have been paramount to the writing of this thesis have not yet been entirely disclosed by its authors. In particular, we refer to the so-called European "taxonomy", which, while this document has been elaborated, has still not been finalized by the Union. Finally, with regards to the research method featured by this document, the author chose to conduct a two step analysis encompassing a case study followed by the impact assesment related to the former. Such structure may result to be excessively redundant in relation to the Hydrogen Valley in development by ENEA, hence failing to capture the entire scope of the impact that hydrogen stars.

Literature review

Current literature seems to ignore the character of mutuality featured by the relationship between energy systems and global warming; in other words, how differently renewable and non-renewable energy sources and carriers impact the environment has been largely studied in recent years, while the consequences of the employment of polluting agents for the structure of energy systems has never been adequately put under the lens, as if the latter can exclusively be conceived as a mere consequence of the former. Instead, it is often forgotten that said items in turn severely impact the degree of efficiency featured by renewable energy sources, specifically non-programmable ones. Such considerations should highlight how strictly energy systems and climate change are intertwined, and in a way less predictable than it may superficially appear. Thus, a thesis on the relationship between sustainable energy and the international community cannot be devoid of a reflection on the consequences for human beings of having designed their society around the exploitation of fossil fuels. At the present stage, the consequences of the phenomenon commonly referred to as Climate Change is negatively impacting every aspect of the biosphere[16], posing a significant risk that the conditions that make planet earth suitable for the proliferation of the human species will fade[17]. In particular, the steadily increasing release of greenhouse gases (GHG) since 1750 has led to a dramatic increase in the concentration of carbon dioxide in the atmosphere[18], reaching an unprecedented average peak between 2011 and 2019 of 410 ppb for carbon dioxide (CO2), 1,866 ppb for methane (CH4), and 332 ppb for nitrous oxide (N2O)[19]. Predictably, these numbers are causing apocalyptic disruptions to the biosphere, which has thus

[16] Malhi, Y., Franklin, J., Seddon, N., Solan, M., Turner, M. G., Field, C. B., & Knowlton, N. (2020). Climate change and ecosystems: Threats, opportunities and solutions. *Philosophical Transactions of the Royal Society B*, *375*(1794), 20190104.
[17] Folke, C., Polasky, S., Rockström, J., Galaz, V., Westley, F., Lamont, M., ... & Walker, B. H. (2021). Our future in the Anthropocene biosphere. *Ambio*, *50*(4), 834-869.

[18] Solarin, S. A., Yilanci, V., & Gorus, M. S. (2021). Convergence of aggregate and sectoral nitrogen oxides in G7 countries for 1750–2019: Evidence from a new panel Fourier threshold unit root test. *Journal of Cleaner Production*, *324*, 129298.
[19] Ibid.

experienced an increase of the global surface temperature at a rate unprecedented in the last two thousand years[20]. More specifically, the global surface temperature in the period 2001-2020 was 0.99°C higher than in the period 1850-1900[21], and it was 1.09°C higher in the period 2011-2020 than in the period 1850-1900[22]. Looking at a more extended period, global surface temperature has increased faster since 1970 than in any other 50-year period in the last 2000 years[23]. As a result, global ice retreat in the northern hemisphere have accelerated sharply since 1950[24]. Hence, from 2011 to 2020, the annual average arctic sea ice area reached its lowest level since 1850[25]. The global level of glacier retreat since the 1950s has been unprecedented[26]. In turn, glacial melting has caused the global mean sea level to rise by 0.20 m between 1901 and 2018. The magnitude of these global warming-related phenomena collectively affects many weather phenomena, such as heatwaves, tropical cyclones, heavy rainfall and droughts[27]. Not only are these phenomena progressively intensifying, but what is of particular concern is their tendency to occur homogeneously in distant and morphologically different areas of the world[28]. Specifically:

- Heat spikes (including heat waves) have become more frequent and more intense in most of the world since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe[29].
- Marine heatwaves have doubled in frequency since the 1980s[30].
- The frequency and intensity of extreme precipitation events have increased since the 1950s over most of the world's landmasses[31].
- In some regions, agricultural and ecological droughts have increased due to increased soil evapotranspiration[32].

[20] ZHENG Jingyun, LIU Yang, HAO Zhixin, GE Quansheng. State-of-art and perspective on global synthesis studies of climate change for the past 2000 years[J]. Quaternary Sciences, 2021, 41(2): 309-322.

[21] Kundu, A., & Mukhopadhyay, S. Climate change impact on the coastal areas of India: A Review.

[22] Ibid.
[23] ZHENG Jingyun, LIU Yang, HAO Zhixin, GE Quansheng. State-of-art and perspective on global synthesis studies of climate change for the past 2000 years[J]. Quaternary Sciences, 2021, 41(2): 309-322.
[24] Yadav, J., Kumar, A., & Mohan, R. (2020). Dramatic decline of Arctic sea ice linked to global warming. *Natural Hazards*, *103*(2), 2617-2621.
[25] Cai, Q., Wang, J., Beletsky, D., Overland, J., Ikeda, M., & Wan, L. (2021). Accelerated decline of summer Arctic sea ice during 1850–2017 and the amplified Arctic warming during the recent decades. *Environmental Research Letters*, *16*(3), 034015.
[26] Yadav, J., Kumar, A., & Mohan, R. (2020). Dramatic decline of Arctic sea ice linked to global warming. *Natural Hazards*, *103*(2), 2617-2621.
[27] Hashim, J. H., & Hashim, Z. (2016). Climate change, extreme weather events, and human health implications in the Asia Pacific region. *Asia Pacific Journal of Public Health*, *28*(2_suppl), 8S-14S.
[28] Huntington, T. G. (2006). Evidence for intensification of the global water cycle: review and synthesis. *Journal of Hydrology*, *319*(1-4), 83-95.
[29] Seneviratne, S., Nicholls, N., Easterling, D., Goodess, C., Kanae, S., Kossin, J., ... & Zwiers, F. W. (2012). Changes in climate extremes and their impacts on the natural physical environment.
[30] van Woesik, R., & Kratochwill, C. (2022). A global coral-bleaching database, 1980–2020. *Scientific Data*, *9*(1), 1-7.
[31] Lehmann, J., Coumou, D., & Frieler, K. (2015). Increased record-breaking precipitation events under global warming. *Climatic Change*, *132*(4), 501-515.
[32] Rezaei, M., Valipour, M., & Valipour, M. (2016). Modelling evapotranspiration to increase the accuracy of the estimations based on the climatic parameters. *Water Conservation Science and Engineering*, *1*(3), 197-207.

- The sharp decrease in monsoon rainfall since the 1950s.[33]
- The increased probability of combined extreme events[34].

Hydrogen: a brief introduction circa its relevance

Like many other energy carriers, hydrogen offers significant advantages in terms of stability, efficiency and versatility[35]. However, its real strength lies elsewhere, namely in its decarbonization potential[36]. Once its technologies are adequately developed, hydrogen will play a key role in decarbonizing hard-to-abate sectors, offering a competitive alternative to electricity in those contexts where the latter may have limitations[37]. In addition, hydrogen can provide flexibility to the electricity system and support the deployment of non-programmable energy (e.g. solar and wind energy) sources by exploiting part of the existing infrastructure network[38].

Hydrogen is, therefore, of crucial importance in reducing emissions along the entire value chain:

- Production: decarbonized or low-emission hydrogen can be produced through a process known as electrolysis, i.e. green hydrogen, or through the integration of carbon capture technologies, i.e. blue hydrogen. The wide range of different modes of production ensures that even diverse companies can integrate hydrogen into their operations, guaranteeing a high penetration of this energy carrier into the economic fabric.
- Transport and Storage: hydrogen can be effectively used as a carrier capable of transporting energy produced from renewable sources to locations far from its place of origin[39]. This can be done either by exploiting dedicated infrastructure or blending into existing gas networks, especially in its early stages of deployment[40]. In addition, hydrogen offers the possibility to increase the storage capacity of the

[33] Naidu, C. V., Durgalakshmi, K., Muni Krishna, K., Ramalingeswara Rao, S., Satyanarayana, G. C., Lakshminarayana, P., & Malleswara Rao, L. (2009). Is summer monsoon rainfall decreasing over India in the global warming era?. *Journal of Geophysical Research: Atmospheres*, *114*(D24).
[34] Smith, M. D. (2011). An ecological perspective on extreme climatic events: a synthetic definition and framework to guide future research. *Journal of Ecology*, *99*(3), 656-663.

[35] Rifkin J (2002) *The Hydrogen Economy: the Creation of the Worldwide Energy Web and the Redistribution of Power on Earth*. New York, NY, USA: JP Tarker.

[36] Griffiths, S., Sovacool, B. K., Kim, J., Bazilian, M., & Uratani, J. M. (2021). Industrial decarbonization via hydrogen: A critical and systematic review of developments, socio-technical systems and policy options. *Energy Research & Social Science*, *80*, 102208.

[37] Van de Graaf, T., Overland, I., Scholten, D., & Westphal, K. (2020). The new oil? The geopolitics and international governance of hydrogen. *Energy Research & Social Science*, *70*, 101667.

[38] Mauro, S. (2022). Le reti gas esistenti sono pronte al trasporto dell'idrogeno. Retrieved 28 April 2022, from https://rienergia.staffettaonline.com/articolo/34753/Le+reti+gas+esistenti+sono+pronte+al+trasporto+dell'idrogeno/Mauro
[39] Mauro, S. (2022). Le reti gas esistenti sono pronte al trasporto dell'idrogeno. Retrieved 28 April 2022, from https://rienergia.staffettaonline.com/articolo/34753/Le+reti+gas+esistenti+sono+pronte+al+trasporto+dell'idrogeno/Mauro

[40] ibid

energy system, an essential aspect for ensuring the dispatch of energy produced from non-programmable sources[41].

- End-uses: in a logic of complementarity between different energy sources and carriers, hydrogen is the ideal solution for the decarbonization of industrial and civil sectors[42]. In particular, the employability of hydrogen appears to be a promising solution for heavy and long-haul transport and non-electrified railway lines[43].

The EU framework and the sustainability of Hydrogen

At this stage, the European legislator has not taken a decision through the instruments of recommendation and regulation on how to structure the production and use of hydrogen legally. However, proposals 2021/0424[44] and 2021/0425[45] have been published concerning a regulation and a directive on standard rules for the internal markets in renewable and natural gas and hydrogen. The purpose of these documents can be summarized as follows:

"(i) to establish the conditions for facilitating the rapid and sustained uptake of renewable and low carbon gases; (ii) to improve the market conditions and increase engagement of gas consumers, (iii) to better account for contemporary security of supply concerns, (iv) to address price and supply concerns at the level of the Union, (v) to recalibrate the structure and composition of regulatory bodies"[46].

In terms of content, what is puzzling is the absence of precise definitions of how this energy carrier should be produced. The increasingly common term 'green hydrogen' does not constitute a *unicum* but rather an implicit reference to the broad color spectrum associated with hydrogen and the various processes and raw materials that can be combined to produce it, each corresponding to a different chromatic quality of hydrogen itself. While green hydrogen indeed constitutes the 'variety' of energy carrier par excellence that does not entail the emission of any quantity of pollutants, it is also undeniable that the recent reopening of the Union to introduce nuclear energy[47] into the energy scene also opened the way to possible alternative experiments that are also non-polluting.

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[41] David, E. (2005). An overview of advanced materials for hydrogen storage. *Journal of materials processing technology*, *162*, 169-177.
[42] Oliveira, A. M., Beswick, R. R., & Yan, Y. (2021). A green hydrogen economy for a renewable energy society. *Current Opinion in Chemical Engineering*, *33*, 100701.
[43] Atteridge, W. J., & Lloyd, S. A. (2021). Thoughts on use of hydrogen to power railway trains. *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy*, *235*(2), 306-316.
[44] Alex, W. (2022). Recast EU Regulation on Gas and Hydrogen Networks [EU Legislation in Progress]. Retrieved 9 June 2022, from https://epthinktank.eu/2022/03/15/recast-eu-regulation-on-gas-and-hydrogen-networks-eu-legislation-in-progress/

[45] Ibid.
[46] Ibid.
[47] Rugi, T. (2022). Ora c'è l'ufficialità: gas e nucleare sono green per l'Unione europea. Retrieved 9 June 2022, from https://economiacircolare.com/tassonomia-green-gas-nucleare/

Thus, many documents with no legal value have been produced over the last five to ten years, suggesting that national bodies should integrate specific technologies through ad hoc frameworks and policies, yet leaving them devoid of any instruction as to exactly through which specific modalities this process should be pursued. Given these factors, the need for systematic intervention aimed at homogenizing the activities at the national and international levels of both regulators and enterprises stands out. In this sense, the increasing attention given to hydrogen valleys, understood in terms of public funding and collaboration with private entities, should not be surprising. It is worth noting that these considerations, generally shared by members of both the scientific and business communities, form the basis of this thesis paper, constituting the elements that have helped to underscore the urgency of an impact analysis having as its object an infrastructure equal to that which will be analyzed in the case study chapter. Several voices, in fact, raise doubts about the actual ability of hydrogen to play the role of pivotal energy carrier of the energy transition[48]. Therefore, it is most urgent to assess, even if only theoretically, the potential of the impact of the activities that will be empirically analyzed within the scope of this thesis, not only at the energy level but also concerning broader contexts, such as the social and urban.

The relationship between Energy and the Social, Economic, Environmental and Urban fabrics

Unsustainable energy sources bear incredibly harmful consequences for the social, economic, environmental, and even urban fabric[49]. The Intergovernmental Panel on Climate Change (IPCC), the leading international body for assessing climate change, stated an unequivocal relationship between human beings, their society and the energy system's architecture designed to meet their energy needs[50]. Therefore, the predominant use of harmful sources has equally harmful effects on the four aspects mentioned above. Except for the environmental one, which has been sufficiently discussed so far, the exact nature of these effects can be schematized as follows:

- Economic: as human activities in areas such as infrastructure, transport, tourism and many other economic sectors are shown to be developing and evolving according to the most popular energy sources[51], it is no coincidence that the increased interest in renewable energies has led to the spread of best practices aimed at decarbonizing the so-called hard-to-abate sectors, such as transport and infrastructures, encouraging the adoption of new zero impact models.
- Social: as mentioned while discussing the relationship between energy systems and climate change, the use of a specific energy source entails a particular environmental impact which, in turn, causes

[48] Armaroli, N., & Balzani, V. (2011). The hydrogen issue. *ChemSusChem*, *4*(1), 21-36.

[49] Briguglio, N., Andaloro, L., Ferraro, M., Di Blasi, A., Dispenza, G., Matteucci, F., ... & Antonucci, V. (2010). Renewable energy for hydrogen production and sustainable urban mobility. *International journal of hydrogen energy*, *35*(18), 9996-10003.

[50] IPCC Sixth Assessment Report (AR6) Release of WG1 Report: The Physical Science Basis of Climate Change – ICCI – International Cryosphere Climate Initiative. (2022). Retrieved 28 April 2022, from http://iccinet.org/ipcc-sixth-assessment-report-ar6-release-of-wg1-report-the-physical-science-basis-of-climate-change/

[51] Ibid.

significant disruption to the social fabric of the country in question. Climate change, for example, is likely to increase migration flows from poorer parts of the world, which are also the most affected by natural disasters and droughts, and to encourage conflicts and clashes over the control of water resources, natural deposits and fertile soil, the availability of which is diminishing[52]. The current pandemic emergency, which is also attributable to the consequences of climate change, constitutes too an excellent example of the dangers intrinsic to the prolonged use of non-renewable resources[53]. Not only that, the impact energy bears on society is even more radicated; as demonstrated by studies conducted by White[54], for instance, there is evidence that a community and its culture will advance proportionally to the level of energy per capita. Even further, the energy system of a certain community constitutes the ideal key to interpret the social, political and organizational dynamics of that same community.

- Urban: since urban areas are often situated in hazardous locations (e.g. along coasts)[55], economic assets and residents that exist therein experience an increasingly elevated risk of being subject to climate-related events. Thus, the urban context urgently needs to be restructured to adapt to the consequences unleashed by the employment of non-renewable sources and mitigate them[56]. Also, as highlighted in the previous paragraph, energy acts as a driver of innovation for communities; to invest in new technologies able to supply citizens with energy more efficiently would entail paving the way for a wave of new, equally innovative services that could sensibly improve their everydayness.

Research Question

Now that the reader has been made aware of the foundations on which this thesis is based, it is possible to introduce in more precise terms the research question which will be attempted to answer. The selected case study, so that the Demo Valley commissioned by ENEA, will be thoroughly described to inform the reader of the technologies therein experimented and how the infrastructure will establish collaboration agreements with external subjects. Once the valley's spectrum of activities and stakeholders will be defined, an impact assessment, performed through a SROI analysis, will be realized as to comprehend the scope and nature of its impact on the economic, social, environmental and urban fabrics of the city of Rome, where the project Is located, and overall Italy, up to now defective of a similar item within its borders. In other words, the objective of this thesis is to lay the groundwork for conducting a quantitative analysis having as its object the impact

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[52] Kaczan, D. J., & Orgill-Meyer, J. (2020). The impact of climate change on migration: a synthesis of recent empirical insights. *Climatic Change*, *158*(3), 281-300.

[53] Chen, C. F., Nelson, H., Xu, X., Bonilla, G., & Jones, N. (2021). Beyond technology adoption: Examining home energy management systems, energy burdens and climate change perceptions during COVID-19 pandemic. *Renewable and Sustainable Energy Reviews*, *145*, 111066.

[54] White, L. A. (1943). Energy and the evolution of culture. *American anthropologist*, *45*(3), 335-356.

[55] Rus, K., Kilar, V., & Koren, D. (2018). Resilience assessment of complex urban systems to natural disasters: A new literature review. *International journal of disaster risk reduction*, *31*, 311-330.

[56] Ibid.

that a hydrogen-based experimentation ecosystem can have in the medium to long term. Contextually, it is worth noting that, within this thesis, it will be analyzed how the infrastructures currently under construction at ENEA will influence not only the energy and, therefore, environmental scenario of the city of Rome and Italy but also the effects that the Demo Valley will generate regarding the social, economic and urban context of the metropolitan city and the country. Therefore, it will be put under the lens how the research and development activity conducted by the Entity in partnership with public authorities and companies will influence the social fabric of the city and what weight the developed technologies will have on the national economy. Finally, consideration will also be made on how the inhabitants of the areas surrounding ENEA's infrastructure will be able to interact with it and, in a broader range of time, the citizens of the entire city.

Methodology

Research Strategy

Considering the nature of the research question, so that the theoretical assessment of the impact of a hydrogen-based experimentation ecosystem on the urban area in which it is located, as well as the larger national context which comprises the city itself, the author decided to adopt an inductive approach to conduct such inquiry. Thus, it has been decided to adhere to a research strategy that may be based on a specific observation from which collect enough materials and data to serve as a solid starting point from which move to more broad considerations and conclusions. To do so efficiently, taking into consideration the vast range of lenses through which the case study will be explored, the author deemed unlikely to obtain satisfying answers to the research question while limiting the scope of this document to a single case study analysis. Thus, it has been decided to additionally integrate an Impact Assessment. Performing a two-step analysis, connected by an inductive approach, should allow for an adequate expansion of the mere observations on the project gathered during the case study phase by extrinsecating them from the original context and pondering upon the innovative potential hydrogen bears. To perform the case study analysis, once selected the object of the latter, the author organized several rounds of interviews with engineers responsible for the development of ENEA’s demo-valley, as well as other professionals active in Technip Energy Solution, a firm active in the energy market linked to ENEA through over a decade long work relationship. Additionally, the author obtained the authorization to consult non-publicly disclosed documents that describe the activities that will be conducted within the demo valley once functional and the typologies of collaboration agreement that will be formed between ENEA and third parties. The impact assessment will thus follow. Such investigation will be conducted through performing a SROI (Social Return On Investments) analysis, so that by forecasting the possible outcomes for the national context hosting the demo valley from the above-mentioned standpoints, that are: economic, social, urban and environmental.

Research Design

Selection of the Case Study

The rationale behind the selection of ENEA's Hydrogen Valley as the sole case study on which this thesis will focus is justified according to several factors. Foremost, although the term "hydrogen valley" is used as an equivalent to "demo-valley", these locutions hint at considerably different items. A hydrogen valley can be defined as a "geographical area, city, region or industrial area where several hydrogen applications are combined together and integrated within an FCH ecosystem"[57], so that a complex of infrastructures specifically designed and built to satisfy the energy demand of a determinate urban area and/or industrial facilities. The term Demo-Valley, on the other hand, still entails the employment of technologies aiming at producing hydrogen, however not in a scale that may be sufficient to provide energy to any external infrastructure. Rather, the aim of a demo-volley is to provide industry players, public authorities and scientific researchers a space in which funding research and development of emerging technologies in the field of hydrogen production, so that they can then move on to the industrial production of those products that will have proved to be particularly efficient and/or consistent with the specific needs of the stakeholders themselves. Currently, the only item that fits such description is the selected case study developed by ENEA. Thus, it would have been vain to include in this thesis any additional analysis focused on "valleys" other than the one already under observation. Also, the author deemed necessary to perform a single case study as it appears to be the tool that better suit a holistic investigation, as the one conducted Is considering the plurality of standpoints from which the impact provided by hydrogen on society Is observed. Additionally, the complexity of the activities performed within the ENEA's Demo Valley as well as the multitude of different stakeholders involved in the project make the object of this thesis not susceptible to any simplifying analysis based on quantification. However, the author Is also aware of the limits that lie in single case studies, foremost the one of researcher subjectivity. As exclusively one item will be analyzed in this document, the opinion of the author may shape the considerations performed in this document thus underpinning its objectivity. In this sense, the author is aware of the importance of highlighting how the conclusions that will be presented in this document are supported by the information gathered from external sources through the mean of interviews.

Performing a SROI analysis

The activities pursued by companies and individuals consequently generate value or dissipate it through the production of changes affecting the surrounding environment. An inherent flaw in the evaluation of these changes is that only the financial gains and/or losses related to these activities are often taken into account. Every expectation other than financial is considered through the means of non-financial reporting, an activity loosely regulated by legislators, which often allows firms to provide mislead or superficial information circa the efforts they spend in terms of positive social impact[58]. As a result, decisions taken upstream of these

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[57] Mission Innovation Hydrogen Valleys Platform. (2022). Retrieved 9 June 2022, from https://www.clean-hydrogen.europa.eu/get-involved/mission-innovation-hydrogen-valleys-platform_en

[58] Hess, D. (2019). The transparency trap: Non-financial disclosure and the responsibility of business to respect human rights. *American Business Law Journal*, *56*(1), 5-53.

processes are often superficial, as they are made based on a partial perspective of the overall impact of these activities. On the other hand, Social Return On Investment (SROI) is an approach for measuring and reporting circa this broader concept of value. It is based on the desire to reduce social inequality and environmental degradation and improve overall economic and social well-being by incorporating aspects that are not exclusively economic in the analysis of costs and benefits. The SROI aims to measure the concept of change based on meaningful parameters for the entire spectrum of stakeholders involved in the activities put under the lens. It provides an account of how the change was generated, the resulting social, economic, environmental and urban outcomes, and the associated equivalent monetary value. It can be said that there are two types of SROI[59]:

- Evaluative, conducted ex-post and based on actual outcomes already achieved;
- Predictive, to predict how much social value will be created if activities achieve the expected outcomes.

The predictive SROI is particularly useful in the planning stages of an activity[60]. It can help highlight how the investment can maximize impact and help identify what should be measured once the project is underway. The lack of reliable outcome data is a significant challenge in conducting a SROI analysis for the first time. To carry out an evaluative SROI, data concerning outcomes will be needed, whereas a predictive SROI will provide the basis for a helpful approach to defining outcomes[61]. Within the scope of this thesis, it was decided to conduct an evaluative SROI, given the lack of a currently functioning evaluation object.

The SROI process unfolds along six stages, which will now be enumerated and later developed more specifically regarding the case study examined in this thesis. The phases of the SROI are thus:

1. Establishing the scope of the analysis and identify the main stakeholders: it is essential to define clear boundaries as to what the SROI analysis will encompass, who will be involved in the process and how.
2. Mapping the outcomes.
3. Assigning value to the outcomes. This step involves finding data to show whether outcomes have been achieved and then evaluating them.
4. Defining the impact. Having gathered evidence of the outcomes and given them a monetary value, it is necessary to ponder circa those aspects of change that would have occurred anyway or that are the result of other factors.
5. Calculating the SROI. This step consists of adding all positive values, subtracting negative ones and comparing outcome and investment.

[59] Krátký, J. (2010). Measuring social return on business support for people at risk of social exclusion by SROI analysis. *Scientific papers of the University of Pardubice. Series D, Faculty of Economics and Administration. 17 (2/2010).*
[60] Ibid.
[61] Ibid.

Research Method

To conduct this study, it has been chosen to conduct a two-step analysis, composed of a case study and, subsequently, an impact evaluation focused on the former. To conduct the case study, a number of technical and bureaucratic documents concerning the infrastructure designed by ENEA have been gathered and thus examined, in order to shape a homogenous analysis of the demo valley which could comprise each aspect of its operations and objectives. More specifically, the author has been provided by ENEA with the technical and economic feasibility study related to the project, which has been elaborated by Technip Energy Solutions, so that the firm responsible for the realization of the infrastructures. The data therein contained have been therefore gathered, analyzed and appropriately filtered as to provide the reader with an in-depth examination of the selected case study that is coherent with the research question examined contextually to this thesis. To gain further insights circa the activities conducted within the demo-valley, as well related to the characteristics of the structure itself, the author also enjoyed the possibility to interview Ing. Deiana, responsible for the experimentations on hydrogen performed by ENEA. Once the reader has been provided with an adequate understanding on the demo-valley and its functioning, the thesis will proceed by focusing on its second core, so that the impact assessment, which will be performed as described in the previous paragraph.

Primary Data

Data belonging to such category will be collected through semi-structured interviews with engineers employed by ENEA in the Demo-Valley project. Their expertise and insights will help in providing adequate information through which develop an accurate impact assessment related to the infrastructure they are currently realizing. Additionally, the author is currently collaborating for a six months-long period with a firm active in the field of renewable energies, with a specific focus on hydrogen, and linked to ENEA by a constant stream of collaboration over the years. Several exponents of said company, namely Technip Energy Solutions, will collaborate with the author to correctly interpret the data gathered with regards to the technologies employed within the demo-valley and offer additional insights through which develop an expertise adequate to approach with sufficient awareness the matter of hydrogen and its overall impact on economy, environment, society and the urban context.

Interview method and questions

Given the will to keep a qualitative component to the research while simultaneously getting data-rich insights, conducting interviews for collected data looks to be the best option for the inquiry. In contrast to questionnaires, which have a closed-ended structure for questions, interviews have an open-ended style that allows the author to get as much information as possible from each question[62]. Furthermore, the author has

[62] Dearnley, C. (2005). A reflection on the use of semi-structured interviews. *Nurse researcher*, *13*(1).

complete discretion over how to frame questions in interviews to effectively answer the research topics[63]. However, to ensure the interviewee is well aware of the nature of the questions that will be posed to them, still they have been provided days before the interview with a document summarizing the nature of the informations needed and a list of macro-areas that will be covered during the conversations.

Conducting the interviews

As already stated, the author chose to include in this thesis semi-structured interviews with representatives from ENEa. Such tool allows for a higher degree of spontaneity during the interaction with the interviewees and to deepen specific insights mentioned during the conversation[64]. Thus, they make easier to explore different scenario linked to the subject matter and shed light to aspects that otherwise would have been left untouched by the study[65].

The author decided to conduct the interviews with the engineers from ENEA through Microsoft Teams, hence scheduling them via mail, as the interviewees are geographically distant. Also considering the pandemic currently occurring, the decision to get in touch with the interviewees through online means appeared to be a preferrable option. At the beginning of each interview, the author asked the interviewees the consensus for the interviews to be registered, to subsequently simplify the process of transcripting the conversations occurred. To further facilitate the process, AI powered softwares were used to perform a real-time transcription.

Secondary Data

It has been decided to employ a systematic approach to review existing research on the subject. This approach allows the author to create a precise plan to design the research while minimizing biases by conducting a thorough review of previous literature[66]. The systematic approach appears to be more beneficial because it helps to funnel the gathered insights into what is needed to answer the research questions, allowing the research to focus on specific issues. Taking this into account, a literature review of existing research that is relevant to the topic is carried out. Its goal is to provide the reader with a comprehensive theoretical basis in the thesis's research subject. With regards to the language of the reviewed literature, works that have been considered were alternatively written in English or Italian.

Case Study

ENEA’s Hydrogen Demo-Valley: birth of the project and operations

[63] Dearnley, C. (2005). A reflection on the use of semi-structured interviews. *Nurse researcher*, *13*(1).

[64] Ibid.
[65] Ibid.
[66] Davis, G. B., & Parker, C. A. (2000). Writing the doctoral dissertation: A systematic approach. *Decision Line*, *31*(2), 19-20.

The project envisages the construction of a multifunctional infrastructure at the ENEA Casaccia Research Centre, which will act as an "incubator"[67] for technologies and services related to the industrial hydrogen chain. Specifically, at C.R. ENEA Casaccia, two transport and distribution infrastructures will be built: a pipeline for the CH4/H2 blend and one for pure hydrogen (hydrogen pipeline), both complete with network auxiliaries and served by some central users[68]. The two pipelines will be connected to hydrogen production systems powered by renewable energy sources and to utilities that will use hydrogen as an energy carrier, thus creating a hydrogen-based ecosystem. On the production side, a 200 kWp photovoltaic system will be installed, coupled with a 200 kWe electrolyser to produce green hydrogen, which will be fed partly into the pipeline for hydrogen mixed with N.G., at varying percentages, and partly into the pipeline for pure hydrogen. The pipeline will serve several utilities: the CH4/H2 blended gas pipeline will supply boilers, a microturbine, fuel cells; an HRS (Hydrogen Refueling Station) will be connected to the pipeline and will be able to power vehicles for internal/external mobility of people and goods, as well as thermal, and cogeneration utilities; a storage system will ensure hydrogen supply/demand modulation. At a higher hierarchical level, a complete data acquisition, control and processing system (H.W. and S.W.) will be implemented for the integrated management of the Hydrogen Demo Valley and for creating a database for future replicability scalability actions in similar contexts. The general objective of the project is to create an integrated infrastructure to demonstrate the feasibility, functionality, sustainability, resilience and security of a hydrogen-based ecosystem, as well as to offer the industry the opportunity to test and validate, in a dedicated ecosystem, technological solutions with different TRL on a significant scale. Expressly, it is foreseen to build and operate multifunctional infrastructures that will allow, with a "technology neutrality"[69] approach, the demonstration and integration of hydrogen technologies to contribute to the achievement of energy transition objectives in the short and long term. The objective is, therefore, to realize and test, within this framework, the integration of processes and infrastructures related to different links of the supply chain:

- production of hydrogen from electrolysis through mature technologies to ensure adequate production of hydrogen, coupling the use of renewable energy produced on-site with electricity of certified renewable origin from the grid;
- production of hydrogen from different energy sources with emerging and pre-commercial technologies according to industrial needs and requirements;
- transport of hydrogen in blend with N.G. through a dedicated pipeline built for the experimentation of CH4/H2 mixtures in different percentages, carrying out the injection of hydrogen into the gas network, in order to evaluate the response of the network and the performance of the connected users (e.g. an

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[67] Bandera, C., & Thomas, E. (2017, June). Startup incubators and the role of social capital. In *2017 IEEE Technology & Engineering Management Conference (TEMSCON)* (pp. 142-147). IEEE.

[68] Technip Energy Solutions (2021), STUDIO DI PREFATTIBILITA' PROPEDEUTICO ALL'ANALISI DI FATTIBILITA' TECNICO-ECONOMICA PER LA HYDROGEN VALLEY CASACCIA, Unpublished Internal Company Document

[69] Tao, Y. A. N. G., & Daojing, S. U. N. (2015). Technology Neutrality. *Studies in Sociology of Science*, *6*(3), 13-19.

industrial boiler integrated into the district heating system of C. R. ENEA Casaccia), as well as the retrofit of conventional gas transport networks for similar applications;

- transport and distribution of pure hydrogen through a local and dedicated hydrogen pipeline;
- construction of a direct refueling station for hydrogen-powered vehicles dedicated to passenger and goods dedicated to the movement of people and goods (buses, cars, industrial trucks);
- electricity production from pure hydrogen and CH_4/H_2 blends with fuel cells (high-efficiency stationary applications);
- power generation in micro gas turbine systems fueled by CH_4/H_2 mixtures;
- validation of innovative components (sensors, flow meters, etc.) dedicated to the gas network with CH_4/H_2 blends and of gas network with CH_4/H_2 blends and data acquisition systems, remote management and supervision of components and sub-systems;
- production of 100% renewable synthetic methane from green hydrogen and CO_2 of biological origin to facilitate the transport and distribution of renewable gas in the grid (in perspective for seasonal geological seasonal geological storage) and to users;
- separation of hydrogen from the CH_4/H_2 mixture upstream of the end-user, in order to supply a single gas network for CH_4/H_2, pure hydrogen and pure methane consumers.

Stakeholders' Engagement

Line Number #	Theme	Advantages	Quotation
#1	**the interest shown by many companies in reference to the progress of the work and the activities that will be initiated once full operability is achieved.**	**While this figure does not provide an idea of the kind of projects that ENEA will be pursuing concurrently with the demo valley, such a high number of demonstrations of interest testifies to the effective will of the economic**	Al momento abbiamo più di una cinquantina di manifestazioni di interesse da parte di aziende che hanno fatto una sorta di endorsement, diciamo così, al progetto e hanno presentato delle lettere di interesse a collaborazioni a sviluppo.

		dimension to integrate hydrogen into its value chains.	
#2	**The objective featured by ENEA to ensure the correct integration of hydrogen-based technologies within the companies' value chain.**	**To reduce the risk to channel robust financial resources into unsuccessful projects.**	In sostanza, il nostro compito statutario è mettere questo spazio a disposizione del sistema Italia. Chi vorrà potrà fare delle attività, commissionandocele o svolgendole assieme a noi. L'obiettivo è sicuramente quello di coinvolgere le aziende, dalle più piccole fino alle grandi imprese, senza avere la pretesa di avere fin da subito le soluzioni in tasca per tutti.
#3	**The variety of stakeholders involved in the activity of defining the future role of Demo-Valley.**	**The fact that not only corporate entities wish to be involved suggests how, once in operation, ENEA's infrastructure will ensure the generation of not only economic but also urban and social benefits.**	vantiamo un dialogo, diciamo pure aperto, sia con soggetti singoli, come aziende, compagnie, sia con soggetti collettivi, come associazioni di categoria, penso a Confindustria in primis, nonché associazioni di settore.
#4	**The willingness demonstrated by technology providers to provide ENEA with the first products on**	**A robust number of technology providers already in line to**	Abbiamo inoltre dei fornitori di tecnologie che, per esempio, ci hanno già messo a disposizione, con la formula del comodato d'uso gratuito, i loro componenti, i loro prodotti, per poter fare dei test e delle integrazioni.

	which to perform testing and fine-tuning activities once the infrastructure is fully functional.	**start co-experimenting with ENEA provides a solid starting base of "clients" to ensure the first round of activities that will attract further interested clients.**	
#5	**ENEA's desire to render the demo valley an infrastructure suitable not only for conveying scientific advances but also to define the best application context regarding each breakthrough to maximize the benefits for the economic and social fabric of the country.**		stiamo fungendo da apripista e vogliamo fare massa critica perché si crei un ecosistema ideale per la nascita di nuove iniziative e progetti. L'idea è poi non fermarsi all'interno dei confini dell'Enea. L'idea è quella di andare fuori dai confini di ENEA e andare a svolgere collaborazioni sulla rete commerciale e su applicazioni commerciali e industriali.
#6	**The activities conducted within the demo valley should progressively convince an increasing number of actors to get involved**	**By vehiculating the success of the projects conducted by ENEA's partners, other players of the**	È un altro il nostro compito, ossia testare le cose, le tecnologie, imparare cose nuove e comunicarle al pubblico. Pubblicare e rendere pubblico e fruibile l'informazione verso l'esterno (…) Andiamo verso un aumento della penetrazione delle rinnovabili

		energy sector should mature the choice to enter the demo-valley's network	

Quotes from the interview with Ing. Deiana, ENEA

At this stage, ENEA has already received more than fifty manifestations of interest from leading companies in the energy sector both in Italy and Europe (See line #1), such as Technip FMC, ENEL, SNAM and others[70]. In this regard, ENEA's work carried out through the demo valley infrastructure is of utmost importance. In the absence of a figure who can act as an intermediary between a company and the implementation of hydrogen-related technologies, the prospect of investing a substantial amount of financial resources in unsuccessful projects is high. This strong risk component boasts the potential to dramatically slow, if not stop altogether, the growth of hydrogen's role in national economic development. In this sense, ENEA's role enables the smooth overcoming of these issues. As pointed out by Engineer Deiana, the different types of consulting services offered concurrently with Demo Valley will allow companies to experience a long study prior to the actual integration of innovative technologies into their business (See line #2). This, combined with the harmonization and refinement of the products involved, will significantly reduce the risks associated with updating the corporate value chain, conveying an efficient amalgamation between hydrogen and the national business fabric. In addition, ENEA has received requests for collaboration from other types of organizations, such as public bodies, including the "Corpo Nazionale Vigili del Fuoco", and trade associations such as CONFINDUSTRIA (see line #3). The inherent importance of these types of collaborations is paramount. They appear to be symptomatic of the emergence of co-governance models through which the implementation of hydrogen-related technologies in the value chain of domestic companies will be standardized and progressively accelerated. If the interest shown by a multitude of companies is, as previously discussed, in itself testimony to the compelling interest of the economic dimension in this energy carrier, the activity pursued by industry associations goes even further. As stated during the interview conducted by the author, their collaboration agreements infer the future structuring of incentives frameworks which will further channel innovation in the direction of hydrogen, thus ensuring a character of homogeneity circa the progress therein performed as well as the benefits enjoyed by actors active along with the whole country. This high number of endorsements testifies to the keen interest shown by industry and the public sector in the project's intrinsic potential. The exact modalities of collaboration between the Demo Valley and the subjects mentioned above will be carried out based on the exact needs of the latter: in particular, numerous technology-provider companies have, through the formula of the free loan

[70] Technip Energy Solutions (2021), STUDIO DI PREFATTIBILITA' PROPEDEUTICO ALL'ANALISI DI FATTIBILITA' TECNICO-ECONOMICA PER LA HYDROGEN VALLEY CASACCIA, Unpublished Internal Company Document

of use, provided ENEA with prototypes of their products so that it can contextually carry out experimentation and integration activities with pre-existing hydrogen-related technologies (see line #4). At the moment, ENEA assumes that, when the infrastructures of the demo valley will be fully functional, the agreements with the above-mentioned entities will be carried out mainly in three forms:

- "Partenariato", so that partnership collaborations between ENEA and one or more entities interested in working together to pursue a common goal related to integrating hydrogen technologies in an economic sector.
- Commissioned research, in which an external entity will channel financial assets within the Hydrogen Valley for the latter to, for example, explore with its own means the degree of applicability and efficiency of a hydrogen-related technology.
- The organisation of calls for tenders in cooperation with regional and/or national bodies to encourage the development of hydrogen-related technologies in specific geographical or economic contexts.

Conclusions

The Italian Peninsula area bears the concrete potential to become a globally important producer and export hub for hydrogen[71]. Such geographical context inherently features the most relevant characteristics to support such transformation: it comprises, or is close to, areas that are optimal for producing renewable energy[72]; it features a state-of-the-art infrastructure for the transport of energy carriers[73], mostly coherent with the technicalities required to move hydrogen[74]. However, the area also suffers from several barriers that prevent hydrogen from being integrated in the current economic dimension at an acceptable pace. Mostly, we can refer to societal and economic barriers[75]. With regards to the former, it is paramount to highlight that how consumers and product developers too tend to be extremely cautious when it comes to adopting new technologies that may disrupt the way they interact with a certain activity and/or how they conduct business[76]. Only after having matured a satisfying degree of familiarity and awareness with regards to a certain innovation the latter will enjoy the possibility to be integrated at a larger scale[77]. As for the economic barriers, it should

[71] Capozza, S., Crema, L., Maggi, C., Testi, M., & Trini, M. (2021). Hydrogen Development in the European Union and Italy-Legislative Barriers and Potential Solutions. *Trento Student Law Review*, *3*(2), 65-98.

[72] Timmerberg, S., & Kaltschmitt, M. (2019). Hydrogen from renewables: Supply from North Africa to Central Europe as blend in existing pipelines–Potentials and costs. *Applied energy*, *237*, 795-809.

[73] Timmerberg, S., & Kaltschmitt, M. (2019). Hydrogen from renewables: Supply from North Africa to Central Europe as blend in existing pipelines–Potentials and costs. *Applied energy*, *237*, 795-809.

[74] Ibid.
[75] Kumar, P., Britter, R., & Gupta, N. (2009). Hydrogen fuel: opportunities and barriers.

[76] Leifer, R., O'connor, G. C., & Rice, M. (2001). Implementing radical innovation in mature firms: The role of hubs. *Academy of Management Perspectives*, *15*(3), 102-113.

[77] Ibid.

be underlined that, at present, the cost associated with hydrogen production and distribution, as well as the ones to be sustained in relation to the materials and components necessary to perform such activities, are still considered to be inefficient if compared to the ones featured by fossil fuels[78]. Such situation originates from the scarce interest demonstrated by players of the energy industry towards hydrogen which, although began to invest considerable amount of assets within this technology, are still far from committing themselves to this new energy carrier with the same effort shown in relation to more "safe" renewable sources of energy[79]. This should not surprise us, as transitioning to new fuels and/or energy carriers entails a relevant risk for companies which expectations, if not met, may provoke their demise. This should explain fairly well why establishing in Italy a hydrogen valley constitutes an action that should be deemed as mandatory to vehiculate an effective shift in the energy scenario. The infrastructure currently in-development by ENEA will in fact, further than what already described in the previous paragraphs, promote a constant stream of collaboration with the academical dimension. To make aware the future representatives of the engineering and energy industry of the potential yet to be developed of hydrogen shall incentivize and facilitate its employment in pre-existent firms (see line #5). Additionally, the opportunity given by ENEA to take active part in conducting studies related to hydrogen within their demo-valley should widen the current scientific literature on the subject[80]. To expand the scientific literature would also pose relevant benefits concerning the above-mentioned societal barriers, as a more capillary dissemination of the advancements performed in the area of hydrogen would entail an increased familiarity of the industry with such subject, hence prevailing over the reluctance of the most conservative ones to renew their business models[81]. Of course, the act of creating an experimentation ecosystem in which test the effective potential of those technologies more of interest to firms active in the energy industry would per se accelerate the diffusion of hydrogen technologies in the Italian industry (see line #6); as mentioned while discussing the economic barriers, in fact, the fear of implementing technologies based on an energy carrier unable to provide the same performances of fossil fuels although a higher price of consumption make most companies desist from investing in this direction[82]. By providing a space in which innovative technical solutions are tested in terms of efficiency and effectiveness, instead, should clear out any significant doubt while evaluating whether or not introducing such innovations in a firm's stream of operations.

Impact Assesment

During this last chapter, the author will proceed to conduct the SROI analysis concerning the Valley demo. The nature of this process has already been put under the lens in the methodology chapter. More specifically,

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78 Oliveira, A. M., Beswick, R. R., & Yan, Y. (2021). A green hydrogen economy for a renewable energy society. *Current Opinion in Chemical Engineering, 33*, 100701.

79 IRENA (2021), Renewable Power Generation Costs in 2020, International Renewable Energy Agency, Abu Dhabi

80 Ibid.

81 Leifer, R., O'connor, G. C., & Rice, M. (2001). Implementing radical innovation in mature firms: The role of hubs. *Academy of Management Perspectives*, *15*(3), 102-113.

82 Kumar, P., Britter, R., & Gupta, N. (2009). Hydrogen fuel: opportunities and barriers.

the social return of this project will be thoroughly analyzed during a specific succession of steps. Theoretically, a SROI analysis begins with a description of the context of analysis, which will, however, be omitted since its object, namely ENEA's infrastructure, has already been analyzed in the case study chapter of this thesis. Next, the stakeholders of the demo valley will be identified, with particular focus on the activities involving each of them. At the end of this step, the outputs that the activities pursued by ENEA will grant the stakeholders themselves according to a pre-specified set of KPIs will be analyzed. The latter will be further employed to lay the base to economically quantify the impact's overall value generated by the project, net of the externalities that would have been a priori generated by third parties (so called deadweight).

Stakeholders' Identification

Stakeholders	Why should we include them	How are they involved	How many are they?	When should we include them?	What Is going to happen to them?
ECONOMIC					
SMEs; start-ups	They constitute the subjects for which the services to be offered by the demo-valley have been thought.	They will establish partnership with ENEA co-developing technologies within the demo-valley's shared infrastructures.	It Is still early to define a precise number of firms that will enter the ENEA's network.	Once the demo valley will be functional, their contractual relationship with ENEA will be established.	They will integrate in their value chains high-end technologies through which disrupt their business models and acquire a privileged position in the market.
SOCIAL					
Universities	They constitute the link through which the activities conducted within the demo-valley	By structuring with ENEA formative courses within the demo-valley.	Although of obvious interest for the academic dimension, it is not possible to forecast the exact number	Once the demo valley will be functional, their contractual relationship with ENEA	They will integrate their formative offer with curricular activities coherent with the evolution of the whole

	will involve students too.		of universities that will effectively enter ENEA's network	will be established.	industrial scenario
Students (Msc; PhD)	By participating in ENEA's courses, they will experience a long-lasting impact which will be reflected contextually to their careers.	They are the subjects which will be enrolled in ENEA's courses within the demo-valley.	Until the project does not start, it is impossible to define the number of students that will participate in the courses within the demo-valley.	Once the demo valley will be functional, the courses will be structured and launched. From that point on, it will be possible to measure the impact on students.	They will acquire core competences that are coherent with the needs of the energy sector's players, thus increasing their own employability.
Citizens (Casaccia; Rome; Italy)	As the demo-valley constitute an item physically integrated in the environment, it will necessarily have an impact of thus inhabiting that same space.	By employing the services made available by the demo-valley's infrastructures.	Progressively, the analysis should consider a broader spectrum of subjects. The ones inhabiting Casaccia in the short term, then the ones living in Rome and in the entire country in the medium and long term.	After ENEA's project has been launched and the services are made available to the public.	Their everydayness will be enriched with hydrogen-based services, which will vehiculate the acquisition of further products, such as cars, that are compatible with said energy carrier.
URBAN					
Citizens (Casaccia; Rome; Italy)	As they inhabit the context in which the project takes place, they will	By witnessing the birth and development of ENEA's infrastructures,	Progressively, the analysis should consider a broader spectrum of	They will experience an impact generated by the demo-	Their everydayness will be enriched with hydrogen-

	experience changes contextually to where they live and how they approach their everydayness.	they will also, by time, be exposed to the technologies therein developed, thus employing them and reacting to the benefits they bring.	subjects. The ones inhabiting Casaccia in the short term, then the ones living in Rome and in the entire country in the medium and long term.	valley only after the latter will become functional and a satisfying number of projects co-conducted by ENEA's business partners will go live.	based services, which will vehiculate the acquisition of further products, such as cars, that are compatible with said energy carrier.
Comune di Roma	It will act as the scenario in which the project will be functional, thus first-hand experiencing the technologies therein developed and experiencing changes accordingly.	It will provide legal and bureaucratical support to ENEA by promoting the activities therein conducted and incentivizing suitable subjects to establish partnerships with it.	The number of subjects contextually involved should be calculated employing as a proxy the inhabitants of Rome.	Progressively, the analysis should consider a broader spectrum of subjects. The ones inhabiting Casaccia in the short term, then the ones living in Rome and in the entire country in the medium and long term.	By hosting such an innovative project, the city will enjoy the opportunity to constitute the scenario in which relevant economic and technological advancements will take place.
ENVIRONMENTAL					
Comune di Roma; Italy	Although the activities conducted within the demo-valley will not directly generate an impact on the environment,	The environmental context of Italy and Rome will experience significant changes according to the description	The number of subjects contextually involved should be calculated employing as a proxy the	An analysis concerning the impact on pollution generated by the demo-valley should be conducted after a robust	Ideally, the activities conducted by ENEA and its partners will drastically decrease the amount of polluting

	the technologies therein developed will have a profound influence over pollution and energy efficiency.	provided in this scheme. Their involvement with ENEA's activity will thus consist in hosting those changes.	inhabitants of Rome and Italy.	enough number of technologies have been developed and integrated in the industry by firms.	agents released in the atmosphere

Stakeholders Engagement chart

Commissioned Research

Companies active in the energy & utilities sector will have the opportunity to contact ENEA to carry out ad hoc research activities focused on specific products/services/technologies/components to map their potentialities, fallacies and related improvement margins. Based on the commissioning company's characteristics, ENEA will also commit its resources related to the demo valley to define the exact modality of implementation of the research object within the company concerned to maximize the positive outputs deriving from the synergy between the two.

SMEs

While the potential of hydrogen has been discussed for years, the actual economic impact of implementing related technologies within the value chain of a specific company is not without a significant margin of risk. For a company's financial resources to be properly invested in a project related to introducing this energy vector into the company's dynamics, it is in the latter's interest to ascertain the validity of the technology itself. ENEA will ensure that small and medium-sized companies active in the Italian market can understand the convenience of a renovation of this magnitude through a ad-hoc study of the processes that a company is considering implementing internally. As such, their business models will be profoundly impacted by the activities pursued by ENEA within the demo-valley, as the collaboration they will establish with the latter will ensure a prolific and risk-free evolution of their value chain through the implementation of innovative technologies linked with hydrogen.

Public Authorities

Public authorities operate in the economic dimension as drivers of innovation, i.e. structuring a framework of policies and incentives to direct investments in research and development in the most promising directions for the Industry. Where governmental and supranational authorities have made clear the relevance of hydrogen in the balance of the world economy, it is appropriate to understand how to shape technologies related to this energy carrier so that economic development is effective and sustainable in the long term.

Co-Research & Development

As an alternative to the commissioned research activity, any interested company will have the opportunity to share space within the demo-valley infrastructure with ENEA’s human resources to experience first-hand the validity of the possible implementation of hydrogen-related technologies in their value chain. This modality, as opposed to the one discussed in the previous section, guarantees the partner companies a more focused analysis on those aspects of the analyzed technology that are more urgent than the urgency manifested by the company itself.

Start Ups

These companies, not older than five years and whose core business is centered on high-end technologies (cloud/quantum computing, IoT, nanotech, etc.), are usually active in niche market contexts, therefore small and with enormous growth potential. However, their tendentially small size, lack of experience and limited financial assets make them highly fragile creatures, which risk succumbing before they have managed to express a fraction of their potential. The importance of ENEA's role is evident: the demo valley will guarantee interested start-ups access to condominium models in which they can benefit from ENEA's expertise and resources. Hence, they will equip themselves with the right tools to achieve a prominent position in the market, securing their survival and constant growth.

Hydrogen Refueling Stations

In order to create a tangible link with the Casaccia community, ENEA will provide hydrogen pumps within the Demo-Valley facilities that can be used by anyone with vehicles powered by this energy vector. The presence of these items will significantly contribute to developing interest in the activities conducted within the facility. It will promote, first at the municipal level and then at the city level by creating additional pumps throughout the metropolitan area, a wider use of hydrogen-powered vehicles.

Citizens

The availability of innovative infrastructures within their neighborhoods is essential in defining an urban regeneration programme. The integration of innovative technologies into the everyday life of citizens is a vehicle for improving life, not only in itself but also since, in this specific case, the distribution of hydrogen pumps makes the effective deployment of ad-hoc vehicles more likely.

PhD/Master’s Degree collaboration agreement

One of ENEA's intentions is to make the demo valley the ideal junction point between the industrial and academic dimensions by creating numerous opportunities for undergraduates and PhD students from partner universities to work as trainees within ENEA's infrastructure.

Universities

The academic dimension will be profoundly affected by the activities conducted by ENEA. in fact, the latter will contribute to increasingly shift the attention of the market and the scientific community to hydrogen, so that universities will be substantially obliged to review the shape of their related courses to offer their students a coherent and punctual education. Collaborating with ENEA themselves and sharing their spaces for research and experimentation purposes will contribute to align the educational offer provided by universities with the direction ENEA and their business partners are marching towards.

Students

University students participating in the courses promoted in ENEA infrastructure will be guaranteed to acquire apex skills in the future job scenario. The opportunity to work closely with engineers who are experts in the field of energy transition will convey a process of knowledge transfer that, together with having access to ENEA's network, will allow graduates and doctoral students to acquire an extremely relevant standing once their experience in Demo Valley is over.

Outcomes Identification

Social Return On Investment – the Impact Map for ENEA's hydrogen demo valley		
Organisation	ENEA	
Objectives	Vehiculate, Promote and Incentivize the development and diffusion of hydrogen production & storage technologies	
Scope	Activity	Making available an experimentation ecosystem in which any external player
	Contract/Funding/Part of organisation	National/International Authority Grant

Stage 1 ------------→		Stage 2 ---------------→		
Stakeholders	Intended Changes	Inputs	Outputs	The Outcomes
Who do we have an effect on? Who has an effect on us?	What do you think will change for them	Description (what do they invest?)	Description (how would you describe the change?)	
SMEs	They fine-tune the technologies that constitute their core business	ENEA's demo-valley contracts → co-R&D/commissioned research fees	Their market position Is strengthened → number of jobs created.	

Start-Ups	The demo-valley acts to them as an incubator/accelerator	ENEA's demo-valley contracts → fee associated with being hosted in the accelerator/incubator	increase in the degree of efficiency of the technology they introduce in the market → number of patents/number of new firms founded.
(Supply Chain) **Providers** [tech; raw m.]	Spike in commissions.	They offer their services and products to ENEA and its partners according to contractual relationships stipulated ad hoc	Getting access to a wider network of firms and similar that collaborate with ENEA.
Local Authorities	Are able to provide citizens/communities with state-of-the-art services.	They incentivize ENEA's activities through ad-hoc frameworks and policies.	They manage more efficiently the spheres that belong to their competence.
Public Authorities	Can comply with supranational regulations.	They shape policies to facilitate and vehiculate the activities promoted by ENEA contextually to the demo-valley; incentivize the involvement with their infrastructures of SMEs, startups and larger firms; directly collaborate with ENEA for the development of innovative technologies	they are now equipped with ideal tools to vehiculate economic G&D.

Citizens (Casaccia; Roma; Italia)	Enjoy innovative services provided in their city/neighborhood.	Time spent by participating in ENEA activities organized to promote the activities conducted in the demo-valley.	Quality of their everydayness significantly improved; enjoy cleaner environment, less polluted air → KG of CO2 saved
Universities	They enhance the quality of their research projects by having access to a high-end experimentation eco-system.	Financial assets and resources to create collaboration agreements with ENEA through which ensure the possibility for their students to increase their knowledge and competences within the demo-valley's infrastructures.	They improve the quality of their educational offer ; get a higher position in international university rankings; more students enroll → students enrolled in STEM courses.
Students (Ph.D; Msc)	Benefit from the opportunity to integrate in their academical career a curricular experience in a high-end context.	Time (at min wage for Ph.D students; at zero wage for Msc students according to Italian regulation regarding curricular stages).	Increased employability and pool of competences → hours spent in the ENEA's courses

Outcome	Stakeholders involved	Indicator	Quantity	Duration	Financial Proxy	Value
		How would you measure it?	How much change was there	Short/medium/long term?	What proxy would you use to value the change?	What is the value of the change?
Enhancement of	Students/PhD	Time spent in courses/progra	Number of students/Ph	Short to medium	Cost to enroll to a	//

competences to get access to work.		ms promoted by the Demo-Valley	D that are involved with ENEA activities		similar course / hours spent in ENEA's courses	
Job generation	Students/PhD	Number of workplaces related to hydrogen created after the operativity of the Demo-Valley	Number of workplaces related to hydrogen created after the operativity of the Demo-Valley	Medium to long.	Number of jobs created in the contextual field	//
Polluction reduction	Citizens, Public and Local Authorities	C02 that would be emitted in relation to services/product that are instead provided through hydrogen-technologies means	Amount of tons of CO2 saved	Short to long (pollution reduction will become more and more consistent as time passes as an effect of the progressive diffusion of hydrogen)	KG of CO2 saved	//
Economic G&D	Public Authorities, SMEs, citizens (?)	Percentage of annual economic growth (GDP) imputable to the introduction of innovative hydrogen tech	Increase in national GDP	Long.	Percentage of annual economic growth (GDP) imputable to the introduction of innovative hydrogen tech	//

High-End technologies dissemination	SMEs, start-ups, public authorities.	Number of patents related to hydrogen tech registrated by firms/entities in general that collaborated with ENEA.	Number of patents related to hydrogen technology registrated by firms that collaborated with ENEA.	Medium to long.	number of start-ups created; number of patents	//
Availability of new services for citizens	Citizens, Local Authorities.	Number of hydrogen stations accessible by the public.	Number of hydrogen stations accessible by the public.	Short to medium.	Hydrogen pumps: market value of hydrogen erogated as fuel to citizens for their hydrogen-vehicles.	//

Outcomes Identification Chart

Enhancement of competences to get access to work

Since the STEM sector requires students enrolled in related university courses to have a set of skills already developed by the end of their studies, the importance of field study programmes such as the ones promoted by ENEA is undoubted. The public attention is increasingly focused on hydrogen and the extent to which this energy carrier will be able to meet the expectations placed on it. Thus, the chance to supplement their academic knowledge with direct experience in a hydrogen valley represents a precious opportunity for a student.

Job Creation

The gradual spread of hydrogen production and storage technologies will lead to an inexorable increase in the number of jobs exclusively available to students with ad hoc skills. The demo-valley project promoted by ENEA will contribute to train individuals capable of filling these positions and, above all, speeding up this process and directing it towards more efficient and coherent goals with the needs of the demand side.

Pollution Reduction

Even if indirectly, the environmental impact characterizing the demo valley will have a far-reaching positive impact, especially in the long term. Where the ENEA facility does not have a significant impact on the environmental context in which it is being built, the technologies that will be developed within it will make a substantial contribution to decarbonizing most of those so-called hard-to-abate sectors of the economy that today constitute the largest source of pollutants released into the atmosphere.

Economic Growth and Development

The demo valley will ensure that a broad spectrum of entities will be able to direct their investment of time and financial resources exclusively towards those technologies that, over time, will guarantee a better return in terms of innovativeness and efficiency. Such polishing of industrial and research activity, in return, will guarantee the Italian economy significant growth thanks to the familiarity that national economic sectors will develop relatively quickly with hydrogen, increasingly described as the engine of the next industrial era.

High-End Technologies Dissemination

The research activity conducted within the ENEA infrastructure, together with the close collaboration with representatives of the industrial dimension, will ensure a rapid proliferation of companies, both start-ups and pre-existing ones, characterized by a core business revolving around hydrogen. Therefore, this phenomenon should provoke the formation of a virtuous circle, whereby the success achieved by companies through the implementation of hydrogen-related technologies in their business should convince their competitors to implement similar innovations to remain consistent with their environment.

Availability of new services

In addition to collaborating with companies and public authorities interested in increasing the innovativeness of their business and the market, the infrastructure managed by ENEA will propose, once in operation, to guarantee the dissemination of hydrogen-related services for citizens in the metropolitan area. In order to spread awareness of the relevance of this energy vector to the communities affected by the demo valley and the projects carried out therein, ENEA will, at the same time, finance the establishment of hydrogen pumps in its valley. It will favor the creation of a thread with the neighborhood that will lead its inhabitants to approach the demo valley and become more sensitive and aware of the urgent need for its tools.

Outcomes Value Attribution

Enhancement of competences to get access to work

In order to measure the project's impact in the area of skills enhancement, it will be necessary to wait a sufficient number of years for a sample of university students and PhD students to participate in the activities in partnership with ENEA and subsequently enter the world of work. The objectivity of the evaluation will be ensured through the choice of quantifiable parameters such as the equivalent cost that people are willing to pay to acquire knowledge and skills similar to those provided free of charge by the courses offered in the project, net of university fees. This criterion is ideal as it reflects the volume of payment that these students would have had to make in order to acquire the skills necessary to enter a related work context. In order to quantify this aspect, reference will be made to two parameters so that a market research and a measurement of the actual increase in competencies boasted by the participating students.

Market research: this activity considers the training courses available to university students and workers wishing to deepen their skills in the field of hydrogen to be able to enter a related work context. First- and second-level master's degrees should be considered, and other educational offers made available by institutions that are not necessarily universities.

Measurement of skills enhancement: to measure how effectively the participants in the courses held by ENEA acquired skills that make them more appealing in the job market than non-participants, the number of hours spent by students in such courses will be considered. Subsequently, said factor will be economically quantified by employing as a parameter the cost per hour featured by similar courses currently offered by different institutions.

Impact Measurement

To measure the impact, the following operation shall be executed:

number of students * ([number of hours per lesson * number of lessons] * economic value per hour)

Job Creation

As mentioned above, one of the most relevant impacts of the project will be to drive the creation of new jobs related to hydrogen production, storage and overall management. In order to validly measure this aspect, an estimate concerning the number of jobs created thanks to the advancements made in hydrogen technology thanks to the efforts spent by ENEA and its stakeholders shall be made.

Impact Measurement

To measure the impact, the following operation shall be executed:

(Number of newly hired students * estimated average RAL)

Pollution Reduction

To estimate the economic value of such factor, the savings in CO_2 obtained through the introduction of more hydrogen-powered vehicles should be considered. In particular, reference should be made to the average amount of kilometers driven in a year by a single car, and the difference in emissions caused by replacing fossil-fueled cars with hydrogen-powered cars should be reflected upon.

Impact Measurement

To measure the impact, the following operation shall be executed:

(number of hydrogen fueled cars * average number of KM run by a car per year) / number of KMs that must be run for 1 KG of co2 to be produced

Economic Growth and Development

Once fully operational, the demo valley will, in the long term, guarantee the possibility for the Italian state to establish itself as the leading hydrogen hub in Europe as well as a player of undisputed global significance. The greater degree of energy autonomy guaranteed by the technologies developed within the demo valley ecosystem and the possibility of exporting the energy surplus and launching profitable activities in collaboration with foreign companies will vigorously support national economic development. Such scenario will result to be extremely fertile for the birth and growth of new thriving start-ups active in the energy market. Thus, the increase of their number will be taken under consideration to provide a criterion through which resume the economic impact of ENEA's demo-valley.

Impact Measurement

Number of start-ups "incubated/accelerated" by ENEA's demo valley * average amount of fundings received by third parties.

High-End Technologies Dissemination

The aim of the ENEA project is to support companies in developing and implementing innovative technologies in their value chain that can make their business model more efficient and sustainable. In order to economically parameterize this crucial aspect, it will be needed to track the number of patents related to high-end technologies introduced by companies that will have collaborated with ENEA's infrastructures. Once the demo-valley will be functional, and a consistent number of companies will have initiated and subsequently extinguished with success their period of collaboration with ENEA, it will be necessary to enumerate the patents therein generated and subsequently consider the economic value of the related projects.

Impact Measurement

Number of patents * average economic evaluation of the projects launched in co-partnership with ENEA

Estimating the Deadweight and Finalizing the SROI

STAGE 4

Deadweight	Attribution	Drop Off	Impact
%	%	%	
What would have happened without the activity	Who else contributed to the change?	Does the outcome drop off in future years?	Quantity times financial proxy, less deadweight, displacement and attribution

Deadweight Measurement Chart

STAGE 5					
	Calculating Social Return				
	Discount Rate (%)		//		
	Year 1 (after activity)	Year 2	Year 3	Year 4	Year 5
Present Value					
Total Present Value					
Net Present Value					
Social Return £ per £					

SROI quantification chart

The tables provided here constitute the tools for assessing the actual social return on investment regarding the project analyzed during this thesis. As mentioned several times, the demo valley Is still an unfinished infrastructure. However, the activities that will be carried out and the type of partners that will participate are already well-defined. Without precise numbers regarding collaborations, projects and the volume of stakeholders involved, it would be premature to make definitive calculations here. Any estimates that can be made at the moment would necessarily be polluted by an excessive degree of approximation so that the results obtained would be grossly approximated, if not illogical and not at all reflective of what will happen within and thanks to ENEA in the future. Nevertheless, what has been done in this last chapter has highlighted the positive nature of the demo valley's potential impact on the social, economic, urban and environmental context. Later, when the project has been functioning for a sufficient amount of time, it will be the ideal tool to carry out the corresponding quantification.

Conclusions

The goal set by this thesis was to critically evaluate the feasibility of a project based on the idea of offering industrial actors the faculty to explore the effective potential of hydrogen-based technologies in a controlled space. In order to succeed, it was necessary to analyze with a case-study approach the only facility in Italy suitable to offer this kind of service. Subsequently, with reference to the Italian context, the analysis was further expanded so as to carefully consider how the activities conducted by ENEA will be reflected in the social, economic, environmental and urban spheres. More specifically, during the last chapter, the necessary tools for conducting an SROI analysis were prepared. This tool is used to quantify in economic terms the social impact of a given activity. Although it was not possible to obtain specific numbers, given the obvious absence of input since the Demo Valley is still quite far from initializing its operation, it was an interesting activity to arrange the SROI framework regarding ENEA's project, and it undoubtedly helped to clarify that the latter's influence will be relevant and beneficial. At the end of this thesis, it is possible to say that a satisfactory answer has been provided to the research question that moved this paper. Not only that, but the analysis conducted throughout this document has also made it possible to make considerations about the growing interest reserved for hydrogen, progressively more identified by companies and policymakers as the possible pivotal element that will make the energy transition feasible. Based on what has been found so far, it is thus possible to look with confidence at the work being done by ENEA and the path it is charting with the creation of the demo valley.

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Interview with Ing. Deiana, ENEA

Speaker 1

Innanzitutto, avrei piacere ad iniziare questa intervista ponendole delle domande di natura generale, concernenti cioè il progetto della Demo Valley e, in particolare, le sue origini. Quali sono state le motivazioni che hanno spinto ENEA ad ideare e lavorare su questo progetto? E, cosa fondamentale, perché basarsi esclusivamente sull'idrogeno e non su altre fonti o su di altri vettori energetici?

Speaker 2

Enea lavora sull'idrogeno da tanto tempo, oltre 25 anni all'incirca. Abbiamo una lunga tradizione di attività sulle celle a combustione e costituiamo, in termini generali, un vero e proprio osservatorio tecnologico, in particolare sullo sviluppo, messa a punto ed integrazione di tecnologie legate alla produzione dell'idrogeno e il suo utilizzo in celle a combustibile di varia natura. Diciamo che l'idea, l'embrione di questo progetto deriva da più fonti: sicuramente l'importanza rappresentata dalla de-carbonizzazione, a sua volta derivante dalla spinta delle fonti rinnovabili. Veniamo da quasi dieci anni di attività su questo gas (l'idrogeno), dapprincipio nato ad uso e consumo dei lavoratori e poi diventato, tra virgolette, sempre più di moda. L'idrogeno, diciamo, costituisce una delle vie più semplici ed economiche per realizzare progetti power-to-gas, proprio perché è il gas più semplice, più leggero nonché il primo ad essere prodotto dagli elettrolizzatori. L'idea è nata già precedentemente all'inizio della pandemia, quando sono stati resi disponibili i fondi relativi al framework di Mission Innovation, un'iniziativa internazionale che ha messo insieme a valle della cop 2015 22 governi più l'unione europea con lo scopo di raddoppiare i finanziamenti in campo energetico indirizzati verso la ricerca pubblica. Questo è stato il primo motore attuativo. Sono confluite all'interno di questo contesto numerosi progetti relativi al mondo dell'idrogeno. A questo riguardo, è opportuno specificare che l'idrogeno non è una fonte energetica, bensì un vettore energetico molto diffuso, una sostanza che è legata ad altri elementi ma che, come elemento in sé, non compare puro in natura. Così è nata quest'idea, e prima della Pandemia è stata presentata al ministero. All'interno della pandemia si sono andate a delineare maggiormente le politiche europee, il green deal, e quindi la cosa (la demo valley) ha acquistato peso ed importanza maggiori, tanto che poi è arrivata la strategia europea. Un'altra necessaria specificazione è che dire che la demo valley si occupi esclusivamente di idrogeno è a ben vedere un'affermazione superficiale: l'obiettivo generale è quello di realizzare in Italia un sistema estremamente più complesso, che trascende l'applicazione singola al singolo settore e alla singola tecnologia, ma mira a indagare l'integrazione lungo tutta la filiera di più tecnologie: produzione, trasporto ed utilizzo, di modo da comprendere che economie possono essere generate mettendo insieme i tasselli.

Speaker 1

Molto bene. Poi, soffermandoci sulle tecnologie di produzione dell'idrogeno, una delle prime cose che salta all'occhio è di come di questo colore esistano contemporaneamente numerose categorie cromatiche. Contestualmente alla demo valley, si direbbe che ad oggi l'interesse principale siarivolto all'idrogeno verde, quindi elettrolisi dell'acqua alimentata da energia a sua volta derivante da eolico da solare, un processo caratterizzato dall'assenza di qualsivoglia impatto ambientale. Tuttavia, Enea sperimenta anche in molti altri ambiti, come ad esempio l'energia nucleare. E proprio in riferimento a ciò si parla di idrogeno rosa quando il suo ottenimento è veicolato attraverso energia derivante da impianti di questo tipo. Lei ritiene che, nel tempo, all'interno della Demo Valley si comincerà a sperimentare anche travalicando i limiti dell'idrogeno verde? Quindi spostandoci sull'idrogeno rosa, o magari l'idrogeno blu che è l'idrogeno greggio a cui semplicemente si applicano tecnologie di CCUS?

Speaker 2

Diciamo che l'idrogeno verde costituisce il perno della strategia trainante. Tuttavia, ricordiamoci che l'idrogeno di suo non ha colore, anzi è trasparente, e in proposito addirittura si stanno facendo studi per collegarlo alla corrente, per renderlo a colori, per dargli un odore. Per questioni di sicurezza, essenzialmente, così come si fa con il gas naturale. C'è anche un filone, quasi un sillogismo, che va un po' sfatato poiché che idrogeno verde equivalga agli elettrolizzatori è un po' una semplificazione. Ad esempio, gli elettrolizzatori, una volta attaccati, per esempio al mix di rete, producono idrogeno verde per la solo per la sola parte di rinnovabili che ci sono in rete. Quindi bisogna un po' chiarire certi aspetti: in questo senso, non è sbagliato affermare che potrebbe essere prodotto idrogeno in tutto e per tutto verde prodotto, tuttavia, da gassificazione di biomasse. Si

tratta in fondo di energia rinnovabile, la gassifico e quello che ottengo è idrogeno verde a tutti gli effetti. È proprio sulla base di questa complessità di fondo che stiamo costruendo una infrastruttura base all'interno del nostro centro di ricerca, peraltro il più grande che abbiamo in Italia, con l'idea di non fermarci, diciamo, a una struttura definita e delimitata, cioè chiusa all'idea di creare delle tecnologie e dei progetti che godano di vita propria, abbiano una loro espansione, anche e soprattutto con la collaborazione delle aziende e delle industrie che sono interessate a proporre temi di ricerca e sviluppo su tecnologie diverse. Ci stiamo interessando, come accennato, ad esempio a sistemi avanzati di produzione di idrogeno dal biogas. Anche parlando dell'elettrolisi stessa, essa ha al suo interno tante tecnologie diverse che, diciamo, hanno ad oggi ciascuna un grado di sviluppo differente, una maturità tecnologica e commerciale differenti, per cui c'è tanto spazio per la ricerca sia sui singoli componenti che nell'insieme. Quindi non ci poniamo limiti in questo senso. Sicuramente però la nostra strategia di lungo periodo è in accordo con la strategia europea, ossia in termini generali procedere in direzione di un mondo ad emissioni zero. Per farlo, il fattore abilitante è spingere per una maggior penetrazione delle rinnovabili. Chiaramente ci sono anche questioni relativi ai costi, quindi pure un obiettivo, diciamo, fondamentale è quello di ridurre, per quanto possibile, il costo specifico di produzione.
Ad oggi, con riferimento alle rinnovabili in generale, siamo tre, 4 o 5 volte sopra ai costi di produzione relativi alle altre fonti fossili. In sostanza, il tema della transizione è fondamentale, ovvio, ma per arrivarci serve un approccio critico per capire quali tecnologie ad oggi possano effettivamente fare da ponte.

Speaker 1

Lei cita i rapporti con le industrie, con le aziende, ma prima di passare all'ambito economico, se possibile, vorrei porle un'altra domanda relativa alla struttura interna della demo valley. Quella di Enea non è infatti la prima Hydrogen Valley presenti in Europa. Ci sono altri esperimenti che vengono condotti in Spagna, in Francia, in Olanda. Ecco la demo Valley di Enea è nata con lo scopo di differenziarsi sotto determinati punti di vista da queste altre sperimentazioni.? C'è un qualcosa nella demo Valley di Enea che la rende più competitiva oppure non sono state prese in considerazione delle dinamiche di questo tipo?

Speaker 2

Diciamo che una delle differenze sostanziali è che quella italiana costituisce una demo valley collocata all'interno di un centro di ricerca. La taglia è quindi probabilmente più limitata rispetto a quanto realizzato nel regno unito, per esempio, specie se pensiamo a progetti che stanno spingendo l'utilizzo dell'idrogeno all'interno della rete gas di distribuzione, oppure progetti che mirano a integrare interi distretti industriali con tecnologie afferenti l'idrogeno e quindi svolte ad ampliare il suo uso nell'ambito industriale. Nel nostro caso, non abbiamo certo le dimensioni di un'industria, infatti siamo all'interno di una piccola cittadella della ricerca, ma ciò che è una peculiarità, è avere un sistema interamente presidiato da ricercatori, e che ci troviamo all'interno di un ambito territoriale che è crocevia della e per la ricerca, estesa a tutti i settori. In Italia abbiamo altre realizzazioni importanti sull'idrogeno, come ad esempio a Bolzano, dove è stata realizatta quella che potremmo definire una sorta di demo valley del trasporto. Se poi teniamo conto che disponiamo da più di 30 anni di quasi 40 chilometri di gasdotti in grado di trasportare l'idrogeno, diciamo da una parte all'altra, dalle zone di produzione alle industrie, come quelle nella zona di Bergamo, alle acciaierie, ad aziende attive nell'industria chimica, ci possiamo rendere conto di quanto sia importante avere a disposizone un qualcosa che metta insieme ed integri le aziende e le rinnovabili. Questa è una delle novità più rilevanti per la filiera che stiamo realizzando qui nella demo valley.

Speaker 1

La ringrazio moltissino. Adesso, spostandoci sulle tematiche economiche, ho avuto modo di leggere che il progetto ad oggi è stato finanziato principalmente attraverso fondi erogati contestualmente alla Mission Innovation; quindi, fondi ammontanti all'incirca a 14 milioni di euro. Con riferimento a questo passaggio ci sono anche, ad esempio, altri attori che stanno finanziando il progetto? Se sì, che tipo di ritorni attendono dal loro investimento?

Speaker 2
A voler essere precisi, quelli messi a disposizione da Mission Innovation non sono fondi europei, bensì sono fondi messi a disposizione dai singoli Stati. Mission Innovation è un'iniziativa intergovernativa che va al di là dell'Europa e mette insieme stati diversi, tra i quali figurano anche USA e Canada. È un progetto legato all'iniziativa anche Clean Energy Ministerial, che è, in pratica, un appuntamento periodico nel quale si incontrano esponenti di vari governi ed autorità di ricerca. In particolare, a riunirsi sono i rispettivi ministri competenti nell'ambito energetico. Se non sbaglio, ogni due anni si incontrano appunto per discutere sulle tematiche legate all'energia, all'ambiente e quindi anche allo sviluppo e al finanziamento della ricerca. missione Innovation ha chiuso nel 2021 la sua prima fase. Adesso siamo a una seconda fase, Mission Innovation due punto zero, dove verranno finanziate altre iniziative, altri temi, tra i quali comunque l'idrogeno rimane una delle challenges. Se poi vogliamo parlare di altri fondi ancora, allora diciamo che dal 2019 ad oggi sono partiti diversi fondi, tra cui ovviamente quelli resi disponibili dal MISE ed il PNRR, la ricerca di sistema elettrico, e numerose altre iniziative parallele che finanziano ancora questi temi. Un altro strumento molto importante è quello del co-finanziamento con protagoniste le aziende interessate a sviluppare determinati prodotti e tecnologie. A riguardo, stiamo cercando di fungere da apripista e vogliamo fare massa critica perché si crei un ecosistema ideale per la nascita di nuove iniziative e progetti. L'idea è poi non fermarsi all'interno dei confini dell'Enea. L'idea è quella di andare fuori dai confini di ENEA e andare a svolgere collaborazioni sulla rete commerciale e su applicazioni commerciali e industriali.

Speaker 1
Ecco, a questo riguardo in che modo esattamente immaginate che si possa creare e portare avanti un legame tra Enea, la Demo Valley e, ad esempio, un'azienda interessata ad un qualsiasi tema come potrebbe essere quello del trasporto, o più in generale interessata ad approfondire le sue competenze sul tema dell'idrogeno? Voi immaginate la Demo Valley fornire un servizio di consulenza? Nel momento in cui una azienda si rivolgerà alla Demo Valley, come immaginate che si svolga il rapporto in esame?

Speaker 2
Diciamo che già al momento abbiamo più di una cinquantina di manifestazioni di interesse da parte di aziende che hanno fatto una sorta di endorsement, diciamo così, al progetto e hanno presentato delle lettere di interesse a collaborazioni a sviluppo, a partire dai campioni, da grandi nomi come Enel, Snam Rete Gas e anche Technip, e sicuramente anche le diverse società di ingegneria che operano nel settore. Abbiamo inoltre dei fornitori di tecnologie che, per esempio, ci hanno già messo a disposizione, con la formula del comodato d'uso gratuito, i loro componenti, i loro prodotti, per poter fare dei test e delle integrazioni. In sostanza, al momento vantiamo un dialogo, diciamo pure aperto, sia con soggetti singoli, come aziende, compagnie, sia con soggetti collettivi, come associazioni di categoria, penso a Confindustria in primis, nonché associazioni di settore. C'è un interesse estremamente forte anche per lo sviluppo della normativa che in tanti ambiti abbisogna di gruppi specifici. Disponiamo di accordi di collaborazione, per esempio anche con altri organismi pubblici, a partire dal Corpo nazionale dei vigili del fuoco. Ci sono tanti interessi, sia orizzontali che verticali, ossia su singole tipologie e su singoli ambiti. E noi contiamo e speriamo rapidamente di mettere su almeno una parte di questa infrastruttura perché inizi a girare il prima possibile. Ci sono mezzi classici di collaborazione verso l'industria, cioé accordi di collaborazione di partenariato, quindi bandi per progetti finanziati sia a livello nazionale che a livello delle regioni. Siamo inoltre disponibili a fare anche ricerca commissionata. In sostanza, il nostro compito statutario è mettere questo spazio a disposizione del sistema Italia. Chi vorrà potrà fare delle

attività, commissionandocele o svolgendole assieme a noi. L'obiettivo è sicuramente quello di coinvolgere le aziende, dalle più piccole fino alle grandi imprese, senza avere la pretesa di avere fin da subito le soluzioni in tasca per tutti.

Speaker 1
Lei cita gli organi pubblici e gli aspetti normativi. A tal proposito, è sotto gli occhi di tutti una certa discrasia, una contraddizione in termini: da una parte, soprattutto sui giornali di settore, si sente molto, anzi sempre più spesso, parlare dell'Italia come il possibile nuovo hydrogen hub europeo, per via della compresenza di diversi fattori, come ad esempio questa importantissima rete infrastrutturale di cui disponiamo e, geograficamente, la vicinanza al Nord Africa, caratterizzato dalla produzione di energia solare. Ma proprio a questo riguardo, nonostante questo insieme di fattori, al contrario di molti altri paesi, non vantiamo una vera e propria strategia nazionale riguardante l'idrogeno, al contrario di paesi come ad esempio la Corea del Sud, che dispongono di strategie "tailored". L'Italia, invecerimane esclusivamente ancorata alla road map del 2050. A suo avviso, tutto ciò che verrà fatto contestualmente alla Valley potrebbe spingere i legislatori nazionali a spingere verso la creazione di infrastrutture normative che vadano a veicolare e incentivare il tipo di ricerca che voi state svolgendo? Notate che questo tipo di interesse si sta già concretizzando in questo senso?

Speaker 2
Diciamo che è un po' il compito della ricerca: mettere a disposizione gli strumenti, testare le tecnologie, ma sfortunatamente non siamo noi a decidere, il decisore finale, il legislatore. È un altro il nostro compito, ossia testare le cose, le tecnologie, imparare cose nuove e comunicarle al pubblico. Pubblicare e rendere pubblico e fruibile l'informazione verso l'esterno, ossia. Poi, diciamo il nostro compito può essere quello di fare ricerche, quella quella di fare la politica, lasciata ovviamente ad altri soggetti.

Speaker 1
La ringrazio ancora. E, sempre parlando di organismi diversi da quelli aziendali, la Demo Valley sta strutturando ad esempio delle collaborazioni con il mondo universitario per avviare dei progetti e/o attività nelle quali saranno protagonisti gli studenti delle lauree STEM e via dicendo? Sono già in attivo dei progetti di questo tipo?

Speaker 2
Assolutamente sì. Abbiamo una lunga tradizione di collaborazione con il mondo accademico, sia in ambito ricerca, assieme ad università sparse in tutta Italia, a partire dai politecnici, quindi sicuramente su argomenti di tipo tecnico, ma non solo, come anche ad esempio in ambito economico, in ambito di sostenibilità ambientale, legale, fino ad arrivare agli studi sociali e agli studi sulla percezione pubblica. C'è tutto un ambito di cui operiamo, e da diverso tempo, sulla comunicazione, comunicazione della scienza, e quindi sulla formazione, così come collaborazioni con studenti per svolgere dottorati di ricerca. Svolgiamo anche azioni dirette verso le scuole superiorie le scuole medie. Questi progetti ricomprendono anche il tema dell'idrogeno. In particolare, stiamo organizzando per settembre una prima summer school sull'idrogeno che sarà dedicata a studenti, laureati e laureandi fatta in collaborazione con l'Associazione dell'Ingegneria Chimica e l'Università Sapienza. Abbiamo quindi in cantiere numerose iniziative sulla formazione e la comunicazione, in collaborazione con il mondo accademico.

Speaker 1
Molto bene. E poi, proprio parlando dei rapporti di Enea con l'esterno, cambiando completamente argomento, spostiamoci sul rapporto che sussiste tra Enea, la Demo Valley e quindi la comunità che geograficamente ospita queste infrastrutture, Casaccia. Avete ad esempio immaginato di poter

implementare delle attività che, in qualche modo, possano veicolare una forma di dialogo, diciamo pure di collaborazione, tra di voi e tutti quei soggetti che abitano le aree immediatamente antistanti i vostri laboratori di ricerca? Si vuole cioè andare a creare una sorta di tessuto sociale molto vivace che leghi ciò che voi fate nella comunità che vi ospita e la Comunità di Casaccia stessa? Vi sono delle attività di questo tipo, anche soltanto immaginate e non necessariamente già avviate?

Speaker 1

Dobbiamo contestualizzare: parliamo di Casaccia, che ospita un centro di ricerca lungo un centinaio di ettari nella campagna a nord di Roma. Abbiamo circa 200 edifici, 1000 persone dipendenti più qualche centinaio di soggetti che vengono da ditte, società e che a vario titolo visitano il centro ogni giorno. Sicuramente il centro ha un impatto su qualunque persona che entra qua dentro, considerando che l'idea che portiamo avanti è sostituire una parte degli utilizzi e dei servizi che oggi vengono attuati su base fossile, penso per esempio al tele-riscaldamento: penso alla mobilità, sia interna che esterna, penso anche banalmente, alle docce, e quindi alla produzione dell'acqua sanitaria, e l'acqua per la mensa. Un domani, una volta operativa la hydrogen valley, tutto questo sarà sostituito con degli impianti alimentati con idrogeno, e questo risultato sarà un qualcosa sotto gli occhi di tutti. Verranno realizzati dei tetti fotovoltaici integrati negli edifici che andranno a produrre energia rinnovabile, la quale a sua volta verrà utilizzata per produrre idrogeno. Anche questo sarà un qualcosa sotto gli occhi di tutti. Andremo quindi ad aumentare anche la dotazione patrimoniale dell'Enea, che avrà delle strutture nuove, dedicate e realizzate ad hoc, come i nuovi gasdotti e quindi alle nuove stazioni di compressione e di distribuzione che appunto entreranno nella dotazione di questa comunità. Sono strutture e infrastrutture che da una parte costituiscono beni di proprietà dell'Enea, ma sono anche un po' infrastrutture e beni dei e per i dipendenti e delle persone che lavorano all'interno di questa cittadella della ricerca. Ecco, in questo ci sarà un impatto per la comunità interna. Se poi vogliamo parlare dei quartiere vicini alle infrastrutture, Il punto è che ce ne sono pochi. Siamo in un contesto molto rurale, abbiamo a fianco giusto un centro abitato che è il centro di Osteria Nuova. Questo conosce bene Enea, considerando che è nato dai dipendenti stessi di Enea all'epoca vollero farsi casa vicino al lavoro. Oltre questo, ci sono degli elementi di condivisione e di partura verso il pubblico, se ad esempio pensiamo al fatto che qui organizziamo delle giornate dove è possibile per chiunque sia interessato visitare le nostre infrastrutture. Abbiamo certamente interesse a trasmettere e rendere conto delle attività che si fanno a livello non solo nazionale ma anche locale.

Speaker 1

La ringrazio. Il punto è che mi premeva alquanto inserire all'interno del mio elaborato una sezione nell quale analizzare il rapporto tra enea e l'environment nel quale la sua organizzazzione svolge le proprie attività. Questo nell'ambito di poter successivamente portare avanti una analisi di impatto anche comprensiva di riflessioni relative alla demo valley ed il rapporto sussistente con tutti quei soggetti che non sono direttamente coinvolti nel progetto ma che ne subiscono pure degli effetti.

Speaker 2

In questo senso dobbiamo anche tenere conto che, storicamente, siamo nati come centro nucleare. Ne deriva che anche se oggi ci possiamo definire cittadella, facciamo riferiemento a delle strutture con dei confini molto ben tracciati, delineati. Chiaramente ci tuteliamo con dei meccanismi di controllo sull'accesso molto rigidi. Non siamo sicuramenre una università open data, inserita in un contesto totalmente. Ecco, come dire, non siamo la Luiss, non siamo a piazza Ungheria, o alla Sapienza con i "baretti dentro e fuori". Siamo più una via di mezzo, un po' sito industriale, un po' città della ricerca, però piuttosto chiusi. La permeabilità c'è. Proprio per questo per noi organizzare open days è tanto importante.

Speaker 1
Certamente. Dunque, passando alle battute finali di questa intervista, perché veramente non vorrei sottrarrle troppo tempo, vorrei muoverci verso tematiche di carattere ambientale. Parlando di idrogeno, voi ritenete che le attività di ricerca e di sviluppo svolte all'interno delle vostre infrastrutture nel momento in cui diventeranno operative al 100%, avranno un impatto sul contesto ambientale sul quale vi appoggiate e, se sì, di carattere positivo, di carattere neutro, di carattere negativo?

Speaker 2
Diciamo che al momento stiamo facendo degli studi preliminari. Noi siamo in una zona confinata, storicamente adibita ad usi industriali, nonostante qui siamo in un contesto abbastanza rurale, abbastanza distante da centri abitati. In qualche modo, spesso siamo percepiti come parco, nel senso che abbiamo tutta una dotazione anche a livello di silvicultura, di botanica, nonché tutta una serie di specie animali, fauna selvatica quindi, che a suo tempo erano state impiantate all'interno del centro per prevenirne l'estinzione. Sembra strano, però qui tra noi ci sono le volpi, ci sono i sambuchi, pini, tutti i tipi possibili di alberi. Si potrebbe dire che lavoriamo in un contesto insieme industriale e naturale. Per quanto riguarda gli impatti ambientali, diciamo andiamo verso un aumento della penetrazione delle rinnovabili. Per cui andiamo verso una riduzione dei consumi essenzialmente di gas naturale, che ad oggi è la sostanza ad esempio più utilizzata per il riscaldamento, quindi andremo certamente a generare un beneficio, perché ridurremo l'impatto di tutta questa serie di processi, di attività inquinanti. Per quanto riguarda poi i nostri impatti, non ne prevediamo di grandi in questo senso, perché con le tecnologie che qua studiamo facciamo sperimentazione, sono di piccola taglia. Anzi, dovremmo andare proprio nella direzione opposta.

Speaker 1
Molto bene davvero. Vorrei quindi terminare questa intervista ringraziandola sinceramente per il tempo che mi ha dedicato e le risposte fornite. Mi saranno di grandissimo aiuto durante la stesura della mia tesi.

Summary of the Thesis

Introduction

Numerous signals indicate the urgency of a change of direction in the world energy systems. The steady increase in energy needs due to the industrialization of emerging economies, the approaching peak of fossil fuel production and growing carbon dioxide emissions pose a significant risk to maintaining the conditions necessary for the survival of the human species. Faced with these considerations, the scientific community is mobilizing to explore all alternative energy sources that are both renewable and characterized by low cost of production. In this scenario, hydrogen is receiving considerable attention in terms of activation of funding channels and publication of European and national frameworks to integrate appropriate technologies. Nevertheless, there are many grey areas related to its production: European and national regulations are often in disagreement about which parameters must be met for the hydrogen in question to be considered sustainable.

Moreover, the efforts directed to the development differ significantly from country to country. Based on the EU Sustainable Finance Taxonomy proposal for a Delegated Act, the European legislator seems determined to grant the qualification of 'sustainable', and therefore fundable, to energy production plants based on the exploitation of fossil gas. This provision aligns with the European Commission's desire to set more permissive limits on the maximum amount of C02 emitted during hydrogen production. The tangible result of these provisions is that soon it will seem paradoxically convenient to channel investments towards the development of hydrogen production technologies that are not at all consistent with the urgencies described at the beginning of this paragraph. As pointed out above, the European Union's behavior does not seem to be in line with that of the respective national authorities. On the other hand, the latter, although mature enough to structure their hydrogen roadmaps in a spirit more genuinely aimed at the value of sustainability, lack alignment with each other. As emphasized by the Hydrogen Council, coordination and standardization factors are vital to pursue and achieve tangible results consistently. In particular, the Council suggests that member states should jointly structure legal and economic frameworks to break down any possible barriers to cross-border collaboration and investments and provide infrastructures that both local and foreign players can use. Therefore, this thesis aims to analyze the activity carried out by ENEA, the Italian national agency responsible for the development of new technologies, regarding the Hydrogen demo valley project, which, once functional, will constitute an ecosystem of experimentation to encourage the development and optimization of the most promising technologies related to the advancements in the subject of hydrogen. It will thus be investigated whether such energy carrier may effectively represent a solution to societal issues deep-seated in the Italian national context. In this sense, the author chose to perform a SROI (Social Return On Investments) analysis on the aforementioned demo valley, which will be focused on four precise aspects: economic, environmental, social and urban. As the project commissioned by ENEA constitutes the first example of Hydrogen Valley in Italy, in fact, it serves as the ideal testbed to understand to what extent hydrogen can positively affect the above mentioned four dimensions.

Research Structure

The study has been organized into five main chapters. The first chapter introduces the research, presenting the background, the research problem, the purpose and the work's limitations. The second chapter is constituted by the literature review of previous research, which provides a basis to support the empirical findings and introduces the reader to the research question. The third chapter concerns the methodology used for the research. It will go through the choice of the research strategy, the research method, the research design and the criteria for data collection and analysis. After having provided the reader with a better understanding of the scope of this thesis, the fourth chapter will be employed for the presentation of the case study. Chapter five will instead focus on the impact assessment related to the case study itself.

Limitations

Although this thesis has been elaborated to constitute a complete document as possible, several difficulties have been encountered during its drafting. The case study, for instance, has been selected due to its undeniable relevance; however, it still consists of a not yet fully launched project. Even by having at disposal a satisfying number of sources concerning its aims and scopes, it has not been possible to form objectively correct statements circa the technologies and activities contextually conducted, but only suppositions. Equally, given the impossibility of empirically observing the project's direct effects on its surroundings, the considerations related to the SROI analysis are also theoretical. It should also be underlined that the sources employed to draft this document have been predominantly provided by ENEA, so that the Authority responsible for the management of the project itself. Although there is no reason to doubt the latter's honesty, the reader's attention should still be brought to the lack of third parties' reflections on the topic. Additionally, it is necessary to highlight that other documents that have been paramount to the writing of this thesis have not yet been entirely disclosed by its authors. In particular, we refer to the so-called European "taxonomy", which, while this document has been elaborated, has still not been finalized by the Union. Finally, with regards to the research method featured by this document, the author chose to conduct a two step analysis encompassing a case study followed by the impact assesment related to the former. Such structure may result to be excessively redundant in relation to the Hydrogen Valley in development by ENEA, hence failing to capture the entire scope of the impact that hydrogen stars.

Literature Review

Current literature seems to ignore the character of mutuality featured by the relationship between energy systems and global warming; in other words, how differently renewable and non-renewable energy sources and carriers impact the environment has been largely studied in recent years, while the consequences of the employment of polluting agents for the structure of energy systems has never been adequately put under the lens, as if the latter can exclusively be conceived as a mere consequence of the former. Instead, it is often forgotten that said items in turn severely impact the degree of efficiency featured by renewable energy sources, specifically non-programmable ones. Such considerations should highlight how strictly energy systems and climate change are intertwined, and in a way less predictable than it may superficially appear.

Thus, a thesis on the relationship between sustainable energy and the international community cannot be devoid of a reflection on the consequences for human beings of having designed their society around the exploitation of fossil fuels. At the present stage, the consequences of the phenomenon commonly referred to as Climate Change is negatively impacting every aspect of the biosphere, posing a significant risk that the conditions that make planet earth suitable for the proliferation of the human species will fade. In particular, the steadily increasing release of greenhouse gases (GHG) since 1750 has led to a dramatic increase in the concentration of carbon dioxide in the atmosphere, reaching an unprecedented average peak between 2011 and 2019 of 410 ppb for carbon dioxide (CO_2), 1,866 ppb for methane (CH_4), and 332 ppb for nitrous oxide (N_2O). Predictably, these numbers are causing apocalyptic disruptions to the biosphere, which has thus experienced an increase of the global surface temperature at a rate unprecedented in the last two thousand years. More specifically, the global surface temperature in the period 2001-2020 was 0.99°C higher than in the period 1850-1900, and it was 1.09°C higher in the period 2011-2020 than in the period 1850-1900. Looking at a more extended period, global surface temperature has increased faster since 1970 than in any other 50-year period in the last 2000 years. As a result, global ice retreat in the northern hemisphere have accelerated sharply since 1950. Hence, from 2011 to 2020, the annual average arctic sea ice area reached its lowest level since 1850. The global level of glacier retreat since the 1950s has been unprecedented. In turn, glacial melting has caused the global mean sea level to rise by 0.20 m between 1901 and 2018. The magnitude of these global warming-related phenomena collectively affects many weather phenomena, such as heatwaves, tropical cyclones, heavy rainfall and droughts. Not only are these phenomena progressively intensifying, but what is of particular concern is their tendency to occur homogeneously in distant and morphologically different areas of the world. Specifically:

- Heat spikes (including heat waves) have become more frequent and more intense in most of the world since the 1950s, while cold extremes (including cold waves) have become less frequent and less severe.
- Marine heatwaves have doubled in frequency since the 1980s.
- The frequency and intensity of extreme precipitation events have increased since the 1950s over most of the world's landmasses.
- In some regions, agricultural and ecological droughts have increased due to increased soil evapotranspiration.
- The sharp decrease in monsoon rainfall since the 1950s.
- The increased probability of combined extreme events.

Hydrogen: a brief introduction circa its relevance

Like many other energy carriers, hydrogen offers significant advantages in terms of stability, efficiency and versatility. However, its real strength lies elsewhere, namely in its decarbonization potential. Once its technologies are adequately developed, hydrogen will play a key role in decarbonizing hard-to-abate sectors, offering a competitive alternative to electricity in those contexts where the latter may have limitations. In addition, hydrogen can provide flexibility to the electricity system and support the deployment of non-programmable energy (e.g. solar and wind energy) sources by exploiting part of the existing infrastructure network.

Hydrogen is, therefore, of crucial importance in reducing emissions along the entire value chain:

- Production: decarbonized or low-emission hydrogen can be produced through a process known as electrolysis, i.e. green hydrogen, or through the integration of carbon capture technologies, i.e. blue hydrogen. The wide range of different modes of production ensures that even diverse companies can integrate hydrogen into their operations, guaranteeing a high penetration of this energy carrier into the economic fabric.
- Transport and Storage: hydrogen can be effectively used as a carrier capable of transporting energy produced from renewable sources to locations far from its place of origin. This can be done either by exploiting dedicated infrastructure or blending into existing gas networks, especially in its early stages of deployment. In addition, hydrogen offers the possibility to increase the storage capacity of the energy system, an essential aspect for ensuring the dispatch of energy produced from non-programmable sources.
- End-uses: in a logic of complementarity between different energy sources and carriers, hydrogen is the ideal solution for the decarbonization of industrial and civil sectors. In particular, the employability of hydrogen appears to be a promising solution for heavy and long-haul transport and non-electrified railway lines.

Research Question

Now that the reader has been made aware of the foundations on which this thesis is based, it is possible to introduce in more precise terms the research question which will be attempted to answer. The selected case study, so that the Demo Valley commissioned by ENEA, will be thoroughly described to inform the reader of the technologies therein experimented and how the infrastructure will establish collaboration agreements with external subjects. Once the valley’s spectrum of activities and stakeholders will be defined, an impact assessment, performed through a SROI analysis, will be realized as to comprehend the scope and nature of its impact on the economic, social, environmental and urban fabrics of the city of Rome, where the project Is located, and overall Italy, up to now defective of a similar item within its borders. In other words, the objective of this thesis is to lay the groundwork for conducting a quantitative analysis having as its object the impact that a hydrogen-based experimentation ecosystem can have in the medium to long term. Contextually, it is worth noting that, within this thesis, it will be analyzed how the infrastructures currently under construction at ENEA will influence not only the energy and, therefore, environmental scenario of the city of Rome and Italy but also the effects that the Demo Valley will generate regarding the social, economic and urban context of the metropolitan city and the country. Therefore, it will be put under the lens how the research and development activity conducted by the Entity in partnership with public authorities and companies will influence the social fabric of the city and what weight the developed technologies will have on the national economy. Finally, consideration will also be made on how the inhabitants of the areas surrounding ENEA's infrastructure will be able to interact with it and, in a broader range of time, the citizens of the entire city.

Selection of the case Study

The rationale behind the selection of ENEA’s Hydrogen Valley as the sole case study on which this thesis will focus is justified according to several factors. Foremost, although the term “hydrogen valley” is used as an equivalent to “demo-valley”, these locutions hint at considerably different items. A hydrogen valley can be defined as a “geographical area, city, region or industrial area where several hydrogen applications are combined together and integrated within an FCH ecosystem”, so that a complex of infrastructures specifically designed and built to satisfy the energy demand of a determinate urban area and/or industrial facilities. The term Demo-Valley, on the other hand, still entails the employment of technologies aiming at producing hydrogen, however not in a scale that may be sufficient to provide energy to any external infrastructure. Rather, the aim of a demo-volley is to provide industry players, public authorities and scientific researchers a space in which funding research and development of emerging technologies in the field of hydrogen production, so that they can then move on to the industrial production of those products that will have proved to be particularly efficient and/or consistent with the specific needs of the stakeholders themselves. Currently, the only item that fits such description is the selected case study developed by ENEA. Thus, it would have been vain to include in this thesis any additional analysis focused on “valleys” other than the one already under observation. Also, the author deemed necessary to perform a single case study as it appears to be the tool that better suit a holistic investigation, as the one conducted Is considering the plurality of standpoints from which the impact provided by hydrogen on society Is observed. Additionally, the complexity of the activities performed within the ENEA's Demo Valley as well as the multitude of different stakeholders involved in the project make the object of this thesis not susceptible to any simplifying analysis based on quantification. However, the author Is also aware of the limits that lie in single case studies, foremost the one of researcher subjectivity. As exclusively one item will be analyzed in this document, the opinion of the author may shape the considerations performed in this document thus underpinning its objectivity. In this sense, the author is aware of the importance of highlighting how the conclusions that will be presented in this document are supported by the information gathered from external sources through the mean of interviews.

Performing a SROI analysis

The activities pursued by companies and individuals consequently generate value or dissipate it through the production of changes affecting the surrounding environment. An inherent flaw in the evaluation of these changes is that only the financial gains and/or losses related to these activities are often taken into account. Every expectation other than financial is considered through the means of non-financial reporting, an activity loosely regulated by legislators, which often allows firms to provide mislead or superficial information circa the efforts they spend in terms of positive social impact. As a result, decisions taken upstream of these processes are often superficial, as they are made based on a partial perspective of the overall impact of these activities. On the other hand, Social Return On Investment (SROI) is an approach for measuring and reporting circa this broader concept of value. It is based on the desire to reduce social inequality and environmental degradation and improve overall economic and social well-being by incorporating aspects that are not exclusively economic in the analysis of costs and benefits. The SROI aims to measure the concept of change based on meaningful parameters for the entire spectrum of stakeholders involved in the activities put under the lens. It provides an account of how the change was generated, the resulting social, economic, environmental and urban outcomes, and the associated equivalent monetary value. It can be said that there are two types of SROI:

- Evaluative, conducted ex-post and based on actual outcomes already achieved;
- Predictive, to predict how much social value will be created if activities achieve the expected outcomes.

The predictive SROI is particularly useful in the planning stages of an activity. It can help highlight how the investment can maximize impact and help identify what should be measured once the project is underway. The lack of reliable outcome data is a significant challenge in conducting a SROI analysis for the first time. To carry out an evaluative SROI, data concerning outcomes will be needed, whereas a predictive SROI will provide the basis for a helpful approach to defining outcomes. Within the scope of this thesis, it was decided to conduct an evaluative SROI, given the lack of a currently functioning evaluation object.

The SROI process unfolds along six stages, which will now be enumerated and later developed more specifically regarding the case study examined in this thesis. The phases of the SROI are thus:

6. Establishing the scope of the analysis and identify the main stakeholders: it is essential to define clear boundaries as to what the SROI analysis will encompass, who will be involved in the process and how.
7. Mapping the outcomes.
8. Assigning value to the outcomes. This step involves finding data to show whether outcomes have been achieved and then evaluating them.
9. Defining the impact. Having gathered evidence of the outcomes and given them a monetary value, it is necessary to ponder circa those aspects of change that would have occurred anyway or that are the result of other factors.
10. Calculating the SROI. This step consists of adding all positive values, subtracting negative ones and comparing outcome and investment.

Conclusions

The goal set by this thesis was to critically evaluate the feasibility of a project based on the idea of offering industrial actors the faculty to explore the effective potential of hydrogen-based technologies in a controlled space. In order to succeed, it was necessary to analyze with a case-study approach the only facility in Italy suitable to offer this kind of service. Subsequently, with reference to the Italian context, the analysis was further expanded so as to carefully consider how the activities conducted by ENEA will be reflected in the social, economic, environmental and urban spheres. More specifically, during the last chapter, the necessary tools for conducting an SROI analysis were prepared. This tool is used to quantify in economic terms the social impact of a given activity. Although it was not possible to obtain specific numbers, given the obvious absence of input since the Demo Valley is still quite far from initializing its operation, it was an interesting activity to arrange the SROI framework regarding ENEA's project, and it undoubtedly helped to clarify that the latter's influence will be relevant and beneficial. At the end of this thesis, it is possible to say that a satisfactory answer has been provided to the research question that moved this paper. Not only that, but the analysis conducted throughout this document has also made it possible to make considerations about the growing interest reserved for hydrogen, progressively more identified by companies and policymakers as the possible pivotal element that will make the energy transition feasible. Based on what has been found so far, it is thus possible to look with confidence at the work being done by ENEA and the path it is charting with the creation of the demo valley.