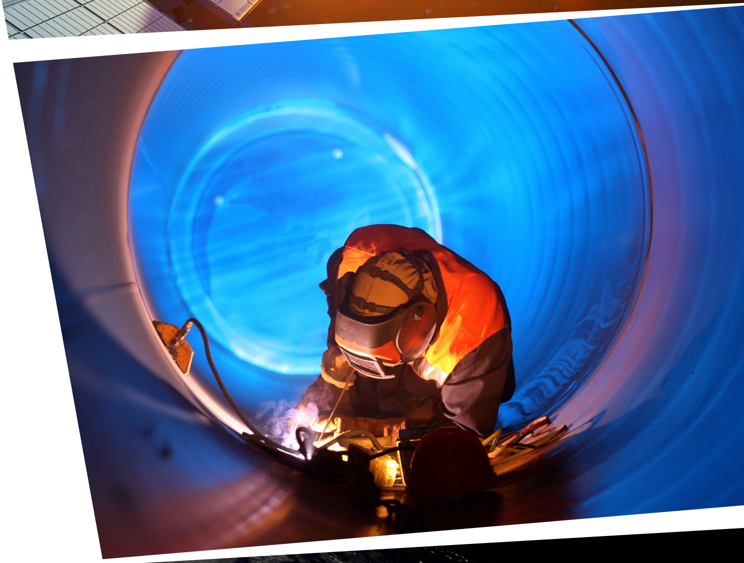
Italy in the International Hydrogen Economy



by Marco Giuli

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Introduction

After many false starts, hydrogen is gaining new traction as a prospective key contributor to deep decarbonisation. Pilot projects, national hydrogen strategies, and international partnerships are proliferating. According to the International Energy Agency (IEA), reaching net zero emissions by 2050 requires hydrogen consumption to rise from 87 MtH_2 in 2020 to 528 MtH_2 in 2050, accounting for about 10 per cent of final energy consumption and 6 per cent of cumulative emissions reduction between 2021 and 2050.[1] In its climate neutrality scenarios, the EU foresees hydrogen to account between 9 and 10 per cent of the final energy demand.[2] Several other scenarios for 2050 locate central estimates for hydrogen demand between 7 and 23 per cent of EU final energy consumption.[3] Besides announcements and scenarios, positive contextual conditions are aligning.

1 The IEA scenario models hydrogen demand in order to fill gaps where electricity cannot economically replace fossil fuels and where limited sustainable bioenergy supplies cannot cope with demand. International Energy Agency (IEA), *Net Zero by 2050. A Roadmap for the Energy Sector*, Revised version (4th revision), October 2021, https://www.iea.org/reports/net-zero-by-2050.

2 European Commission, *A Clean Planet for All. In-depth Analysis in support of the Commission Communication COM(2018)773*, 28 November 2018, https://ec.europa.eu/clima/document/download/dc751b7f-6bff-47eb-9535-32181f35607a_en.

3 See European Climate Foundation (ECF), *Net-Zero by 2050: From Whether to How. Zero Emissions Pathways to the Europe We Want*, September 2018, https://europeanclimate.org/resources/a-net-zero-emission-european-society-is-within-reach-but-getting-there-starts-today-2; Wouter Terlouw et al., *Gas for Climate. The Optimal Role for Gas in a Net-Zero Emissions Energy System*, Utrecht, Navigant, 18 March 2019, https://gasforclimate2050.eu/?smd_process_download=1&download_id=282; DNV, *Heading for Hydrogen. The Oil and Gas Industry's Outlook for Hydrogen, From Ambition to Reality*, May 2020, https://www.dnv.com/oilgas/hydrogen/heading-for-hydrogen.html; Ioannis Tsiropoulos et al., "Towards Net-Zero Emissions in the EU Energy System by 2050. Insights from Scenarios in Line with the 2030 and 2050 Ambitions of the European Green Deal", in *JRC Technical Reports*, 2020, https://op.europa.eu/s/vJEs.

Hydrogen can serve the energy transition in multiple ways. As a light, storable, molecule-based element whose combustion produces no carbon emissions, it can replace fossil fuels in final uses where electrification is not an ideal or a feasible decarbonisation option, as in heavy load, long haul maritime transport. It can replace carbon as a reactant in energy intensive industries (EIIs) such as steel and refining. It can provide a storage solution for intermittent renewable electricity, complementing short-term balancing solutions such as grid-scale batteries and capacity mechanism, and seasonal solutions such as hydro-pump storage. As an energy carrier, hydrogen can allow the long-distance transport of clean energy.

However, hydrogen production is currently highly emissive.[4] At the moment, decarbonising hydrogen production through available routes raises hydrogen costs from a 0.5-1.6 US dollars/kgH_2 range[5] to 2-8.4 US dollars/kgH_2 range, making it uncompetitive with existing alternatives[6] (Table 1). At clean hydrogen production costs foreseen for 2030, it would take a very high carbon price for hydrogen to make inroads into final markets.[7] Yet, if clean hydrogen production is reduced to 1 US dollars/kgH_2, as some estimates expect for 2050, carbon prices[8] in the 50-60 euro/tCO_2e range would be sufficient to enable the competitive production of hydrogen-based steel, dispatchable power and almost sufficient to produce green ammonia.[9]

4 In 2019, hydrogen production – at 95 per cent through steam methane reforming (SMR) and auto-thermal reforming (ATR) and through coal gasification – caused emissions for about 830 MtCO_2 at global level, amounting to 2.5 per cent of global emissions. IEA, *The Future of Hydrogen. Seizing Today's Opportunities*, June 2019, https://www.iea.org/reports/the-future-of-hydrogen.

5 IEA, *Global Hydrogen Review 2021*, October 2021, https://www.iea.org/reports/global-hydrogen-review-2021.

6 IEA, *The Future of Hydrogen*, cit.

7 Assuming for 2030 a price of renewable hydrogen averaging at 3.7 euro/kgH_2 and gas prices at 20 euro/MWh, it would take a carbon price of 300 euro/tCO_2 to make green hydrogen more convenient than gas-based hydrogen, while lower estimates already see a potential cost-competitiveness at between 100 and 200 euro/tCO_2, while 100 euro/tCO_2 would be sufficient for blue hydrogen to be cost-competitive with grey hydrogen assuming a 75 per cent carbon capture rate. See Matthias Schimmel et al., *Making Hydrogen Cost-Competitive. Policy Instruments for Supporting Green H_2*, Berlin, Agora Energiewende and Guidehouse, August 2021, https://www.agora-energiewende.de/en/publications/making-renewable-hydrogen-cost-competitive.

8 Hereby considered at around 60 euro/tCO_2e (EU ETS future prices in October 2021). See Ember website: *Daily Carbon Prices*, https://ember-climate.org/data/carbon-price-viewer.

9 BloombergNEF, *Hydrogen Economy Outlook. Key Messages*, 30 March 2020, https://assets.bbhub.io/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf.

Table 1 | Hydrogen taxonomy[10]

	Classification	Energy feedstock	Process	Waste product/ kgH_2	Technology readiness level (TRL)	Cost \$/kgH_2 (33.6 $kWhH_2$)			Input/ kgH_2 (33.6 $kWhH_2$)
						2020	2030	2050	
Emissive hydrogen	Yellow	Grid electricity	Water electrolysis	<38 $kgCO_2$ Depending on power mix	9	NA	NA	NA	50-55 kWhe 9.1l water
	Black	Black coal	Coal gasification	18-20 $kgCO_2$	9	0.95-1.90	NA	NA	7.5 kg coal
	Brown	Lignite			9				
	Grey	Natural gas	Steam methane reforming (SMR)/Auto-thermal reforming (ATR)	6-9 $kgCO_2$	9	1-2.40	NA	NA	3.8-4.5m^3 gas 5.7 kWhe 4.45l water
Clean hydrogen	Blue		SMT/ATR + carbon capture and storage (CCS)		8	2-5	1.04-3.5	0.74-2.96	
	Turquoise		Methane pyrolysis	3 kg solid carbon	6	NA	NA	NA	5.54 kWh gas 5k Whe
	Red	Biomass, waste	(several processes)	NA	5	NA	NA	NA	
	Green	RES-generated electricity	Water electrolysis	-	6-9 depending on electrolyser technology	2.5-8	1.06-6.42	0.52-4.06	50-55 kWhe 9.1l water
	Pink/purple	Nuclear-generated electricity				NA	NA	NA	
	White	NA	Byproduct of industrial processes	NA	NA	NA	NA	NA	NA

10 Ranges are calculated on the basis of various sources: International Renewable Energy Agency (IRENA), *Hydrogen: A Renewable Energy Perspective*, Abu Dhabi, IRENA, September 2019, https://www.irena.org/publications/2019/Sep/Hydrogen-A-renewable-energy-perspective; DNV, *Heading for Hydrogen*, cit.; IEA, *The Future of Hydrogen*, cit.; Aurora Energy Research, *Hydrogen in the Northwest European Energy System*, August 2020, https://auroraer.com/?p=370; Hydrogen Council, *Path to Hydrogen Competitiveness. A Cost Perspective*, 20 January 2020, https://hydrogencouncil.com/en/?p=3329.

Besides cost components based on technological advancements (i.e. electrolysers' cost and load factors,[11] or technologies for carbon capture and storage (CCS) or hydrogen storage), locational cost components are present. These include the cost and availability of carbon-free electricity; the abundance of natural gas; the availability of water and geological formation such as salt caverns and rock caverns. As these assets are unevenly distributed, production cost estimates depend on regional specificities. At the same time, demand is expected to concentrate around large industrial clusters in advanced economies, where the production of clean hydrogen might be constrained by a lack of favorable locations or social acceptance. In addition, the multiple conversions that are typical of hydrogen supply chains (i.e. electrolysis, liquefaction, dehydrogenation) cause energy losses and low roundtrip efficiency,[12] which could be mitigated by a systemic dimension and inter-sectoral integration. To this extent, international trade in hydrogen and hydrogen products can lower the cost of access clean energy in the long term. Similarly, the internationalisation of hydrogen-related technologies would lower the cost of clean hydrogen production, helping to accelerate its uptake and contribution to decarbonisation. Early movers have chances to strategically position themselves in international hydrogen value chains, enhancing the competitiveness of their own hydrogen supply and selling hydrogen-related technologies to the rest of the world.

11 IEA, *Global Hydrogen Review 2021*, cit.; IRENA, *Green Hydrogen Cost Reduction. Scaling up Electrolysers to Meet the 1.5⁰C Climate Goal*, Abu Dhabi, IRENA, 2020, https://www.irena.org/publications/2020/Dec/Green-hydrogen-cost-reduction; Matthias Schimmel et al., *Making Hydrogen Cost-Competitive*, cit.

12 Energy losses occur first with the electrolysis process, as it takes 50-60 kWh of green electricity to produce 1 kgH_2, which contains 33-40 kWh for a fuel production efficiency of 60-70 per cent. However, when adding transport, storage and distribution, fuel cell conversion, inversion DC/AC and engine efficiency, roundtrip efficiency of fuel cells electric vehicles (FCEVs) powered by hydrogen declines to 22-27 per cent, in contrast to 70 per cent overall efficiency of battery electric vehicle (BEVs). See Felix Chr. Matthes et al., *Die Wasserstoffstrategie 2.0 für Deutschland. Untersuchung für die Stiftung Klimaneutralität*, Berlin, Öko-Institut, 13 May 2021, https://www.oeko.de/publikationen/p-details/die-wasserstoffstrategie-20-fuer-deutschland. Hydrogen-based fuels such as synthetic methanol or ammonia (direct combustion) show 53-62 per cent roundtrip efficiency if based on electrolytic hydrogen. Hydrogen liquefaction implies 25-35 per cent of energy loss in the liquefaction process. See Ramin Moradi and Katrina M. Groth, "Hydrogen Storage and Delivery: Review of the State-of-the-Art Technologies and Risk and Reliability Analysis", in *International Journal of Hydrogen Energy*, Vol. 44, No. 23 (3 May 2019), p. 12254-12269. Hydrogen conversion into ammonia costs 7-18 per cent of the original energy content, and similar losses in case of re-conversion into hydrogen. See European Union Agency for the Cooperation of Energy Regulators (ACER), *Transporting Pure Hydrogen by Repurposing Existing Gas Infrastructure: Overview of Existing Studies and Reflections on the Conditions for Repurposing*, 16 July 2021, https://nra.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/Forms/DispForm.aspx?ID=282.

Countries' positioning in such a picture would depend on a mix of existing assets and policy actions. Such a positioning can define countries' opportunity to pursue at the same the decarbonisation of their economy and the enhancement of their industrial leadership and international competitiveness. The objective of this paper is to explore the potential for Italy to achieve centrality in an international hydrogen economy, to identify enabling frameworks and key challenges, and what policy actions are required to support a competitive positioning.

1. Italy in the international hydrogen economy

This section looks at how Italy's assets locate the country into prospective international hydrogen value chains. Large lead markets, access to clean electricity and natural gas, infrastructural abundance and a favorable geographical position constitute key factors for laying the basis of geoeconomic centrality in the earlier stage of hydrogen development. Later on, developing trans-national connectivity would require physical networks, stable political relations and a shared vision with partners regarding technological choices, infrastructural and contractual standards.

1.1 Demand side assets

A competitive positioning on international hydrogen value chains requires for early movers to create lead markets that justify upstream investment and pave the way for incremental innovation and cost reduction.[13] To this extent, demand size in present or prospective hydrogen-consuming sectors such as EIIs, transport, residential heating and power generation is an asset anticipating a country's role in future hydrogen value chains.

13 Tomas Wyns et al., *Industrial Transformation 2050. Towards an Industrial Strategy for a Climate Neutral Europe*, Institute of European Studies, https://brussels-school.be/publications/other-publications/industrial-transformation-2050-towards-industrial-strategy-climate.

Italy is an export-oriented economy with a sizeable manufacturing base. Italy's current use of hydrogen (480,000 tH_2/yr) is almost entirely dedicated to the production of ammonia and for hydrocracking[14] in the refining industry. As an already existing market for (largely grey) hydrogen, the chemical and refining industry is well placed to kickstart clean hydrogen demand. Italy accounts for just 3 per cent of European ammonia production capacity though, suggesting a smaller market than other comparable clean hydrogen actors in Europe. However, one should consider the locational benefits of the integration of hydrogen production and refineries in Sicily[15] – a region with abundant solar power potential and gas connectivity with North Africa. Switching current hydrogen use for hydrocracking and ammonia production to green hydrogen would require additional 23-27.6 TWh/yr of renewable electricity, amounting to about one quarter of Italy's RES-based electricity production in 2019.[16] Decarbonising such a production through blue hydrogen requires 2.16 bcm of natural gas annually.[17]

The steel sector also deserves attention. Italy is the 11th crude steel producer at global level, and the second in Europe after Germany. In 2019, Italy produced 23.2 Mt of crude steel,[18] accounting for 14.6 per cent of EU production. Italy's plants mostly adopt the scrap-electric arc furnace (EAF) secondary steelmaking route, whose emissions are mostly indirect and whose deep decarbonisation pathways can be provided by circularity and material efficiency without the use of hydrogen.[19] With respect to primary steelmaking in the blast furnace-

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14 Hydrocracking is a process by which the hydrocarbon molecules of petroleum are broken into simpler molecules, as of gasoline or kerosene, by the addition of hydrogen under high pressure and in the presence of a catalyst.

15 Ben McWilliams and Georg Zachmann, "A New Economic Geography of Decarbonisation?", in *Bruegel Blog*, 8 November 2021, https://www.bruegel.org/?p=45190.

16 BP, *Statistical Review of World Energy 2020*, June 2020, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf.

17 Not additional, as the unabated SMR process is currently in use.

18 World Steel Association website: *Annual Steel Data (Total Production of Crude Steel)*, https://worldsteel.org/steel-by-topic/statistics.

19 Material Economics, *Industrial Transformation 2050. Pathways to Net-Zero Emissions from EU Heavy Industry*, 2019, https://materialeconomics.com/publications/industrial-transformation-2050. However, hydrogen could be used in secondary steelmaking to decarbonise side-processes such as the pre-treatment of hot rolling: Nel, *Nel ASA: Receives Purchase Order for 20MW Alkaline Electrolyser from Ovako*, 25 November 2021, https://nelhydrogen.com/press-release/nel-asa-receives-purchase-order-for-20mw-alkaline-electrolyser-from-ovako.

basic oxygen furnace (BF-BOF) plant in Taranto,[20] the direct use of hydrogen (H-BF) could only partially reduce emissions,[21] requiring the addition of CCS technologies to improve the decarbonisation potential further still. On the other hand, the plant's planned conversion to the direct reduction of iron (DRI) route could allow up to 95-100 per cent emissions reduction by using clean hydrogen as the only reactant (H-DRI/EAF route) instead of natural gas.[22] Assuming 6Mt of annual primary steel production, the H-DRI route would require about 21-25 TWh of renewable electricity, amounting to about 22.1 per cent of Italy's RES-based power generation in 2019.[23] In case of utilisation of blue hydrogen, the conversion of the Taranto plant to the H-DRI route would require 1.19 bcm of gas, amounting to 1.7 per cent of the Italian natural gas consumption in 2019. However, converting primary steel production to the H-DRI route is expected to take time. Under current estimates,[24] a maximum of 500,000 t_{steel} could be produced through green hydrogen by 2030, requiring 1.75-2 TWh of additional renewable electricity.[25]

Hydrogen could also make inroads in other EIIs, as a fuel replacing natural gas for high temperature industrial heating processes. Target sectors include glass, ceramic, cement, and paper. However, the use of hydrogen in these sectors is not deemed as a promising decarbonisation pathway[26] – as electrification or carbon capture and storage, among others, may prove more competitive. Competing alternatives and the exposure of these sectors to international competition ultimately reduce the prospects for these sectors to be instrumental to demand creation.

20 Eurofer, E*uropean Steel in Figures 2020*, June 2020, https://www.eurofer.eu/publications/archive/european-steel-in-figures-2020.

21 Bellona Europa, *Hydrogen in Steel Production: What Is Happening in Europe. Part One*, 4 March 2021, https://bellona.org/news/climate-change/2021-03-hydrogen-in-steel-production-what-is-happening-in-europe-part-one; Tomas Wyns and Matilda Axelson, *Decarbonising Europe's Energy Intensive Industries. The Final Frontier*, Institute of European Studies, 2016, https://researchportal.vub.be/en/publications/decarbonising-europes-energy-intensive-industries-the-final-front.

22 Juan Correa Laguna et al., "Carbon-Free Steel Production: Cost Reduction Options and Usage of Existing Gas Infrastructure", in *EPRS Studies*, April 2021, https://op.europa.eu/s/vJTc.

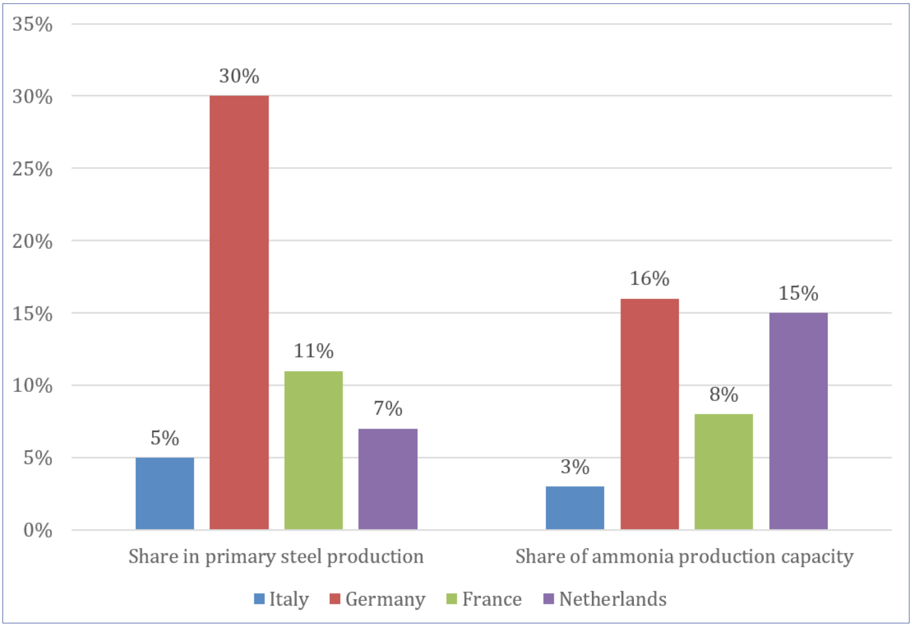
23 Estimation is based on 3.48 MWh/t_{steel}, based on: Valentin Vogl, Max Åhman and Lars J. Nilsson, "Assessment of Hydrogen Direct Reduction for Fossil-Free Steelmaking", in *Journal of Cleaner Production*, Vol. 203 (1 December 2018), p. 736-745, https://doi.org/10.1016/j.jclepro.2018.08.279.

24 Fuel Cells and Hydrogen Joint Undertaking (FCH JU), *Opportunities for Hydrogen Energy Technologies Considering the National Energy and Climate Plans – Italy*, August 2020. https://www.fch.europa.eu/node/3135.

25 Ibid.

26 Matthias Schimmel et al., *Making Hydrogen Cost-Competitive*, cit.

Figure 1 | H_2 demand opportunities,
selected countries and sectors, share of EU28 (2019)



Source: Eurostat.

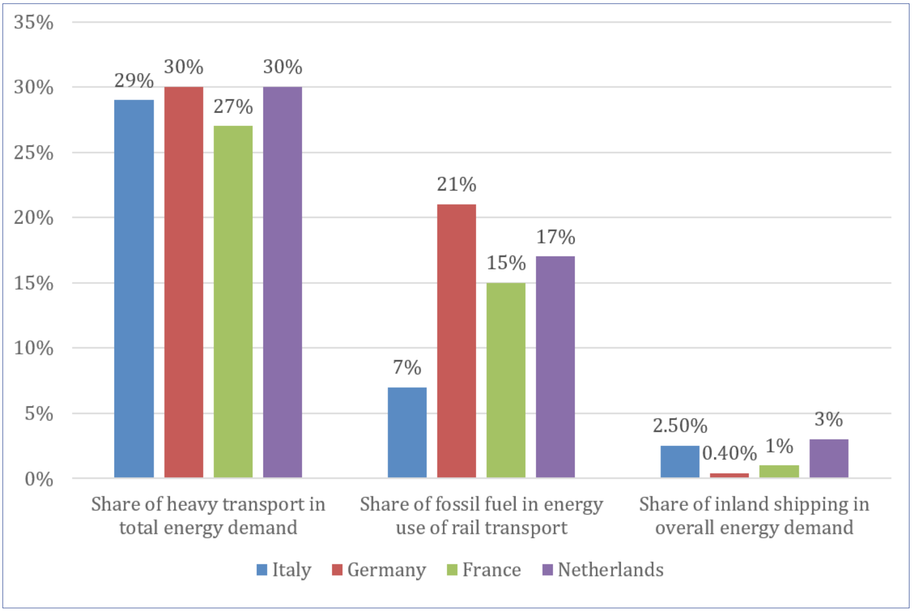
In contrast to EIIs, long-haul heavy duty transport has the advantage of being a non-tradable sector, which means it could drive the early adoption of hydrogen technologies without the risk of losing out to foreign competitors in the short term.[27] Heavy trucks and buses account for almost 30 per cent of final energy demand in transport – a comparable level to other European countries with high hydrogen ambitions (Figure 2). On the other hand, less opportunities arise from railway transport, which is electrified to a larger extent than other EU countries (Figure 2) – yet, 4,763 km of rail network are still served by diesel trains, with domestic actors already working on their conversion to hydrogen.[28] Domestic navigation significantly contributes to Italy's emissions, with a larger share of energy demand than other comparable countries. According to

27 Sonja van Renssen, "The Hydrogen Solution?", in *Nature Climate Change*, Vol. 10, No. 9 (September 2020), p. 799-801, https://doi.org/10.1038/s41558-020-0891-0.

28 Confindustria, *Piano d'azione per l'idrogeno*, September 2020, https://www.confindustria.it/home/policy/position-paper/dettaglio/piano-azione-idrogeno.

industry estimates, transport in Italy is projected to absorb between 57,330-156,800 tH_2 by 2030, requiring 3.15-8.64 TWh of additional renewable electricity in case of exclusive use of green hydrogen.[29]

Figure 2 | H_2 lead markets – transport



Source: FCH Joint Undertaking.

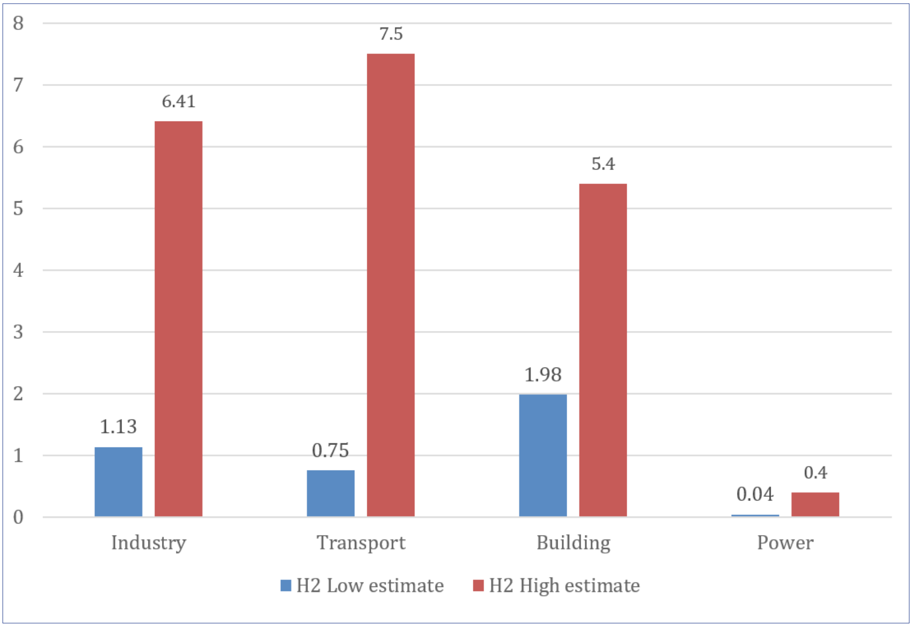
A high share of gas in residential heating (51.79 per cent against 38.76 per cent in Germany) and power generation (44.5 per cent against 14.9 per cent in Germany)[30] could provide a base for short-term demand development through blending. Hydrogen can be blended with gas in the distribution grid for up to 10-15 per cent with no major adaptation. Yet, such an option would be at best a transitional one, while a long-term switching of these sectors towards a 100 per cent hydrogen use is generally discouraged by current grey and academic

29 FCH JU, *Opportunities for Hydrogen Energy Technologies Considering the National Energy and Climate Plans – Italy*, cit.

30 Eurostat database: *Share of Fuels in Final Energy Consumption*, https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_ind_fecf&lang=en.

literature on grounds of prospective costs,[31] efficiency and safety reasons,[32] unless hydrogen is not adopted in large existing district heating systems,[33] which are however uncommon in Italy.[34]

Figure 3 | Clean H_2 demand estimates by 2030 (Italy), $TWhH_2$



Source: FCH Joint Undertaking.

31 Blending requires no upfront investment in the distribution grid, but requires changing metering from volumetric to calorific units.
32 Nixon Sunny, Niall Mac Dowell and Nilay Shah, "What Is Needed to Deliver Carbon-Neutral Heat Using Hydrogen and CCS", in *Energy & Environmental Science*, Vol. 13, No. 11 (November 2020), p. 4204-4224, https://doi.org/10.1039/D0EE02016H; Mark Barrett and Tiziano Gallo Cassarino, *Heating with Steam Methane-Reformed Hydrogen – A Survey of the Emissions, Security and Cost Implications of Heating with Hydrogen Produced With Natural Gas*, Oxford, Centre for Research into Energy Demand Solutions, October 2021, https://www.creds.ac.uk/?p=7029.
33 Minhea Catuti et al., "Is Renewable Hydrogen a Silver Bullet for Decarbonisation? A Critical Analysis of Hydrogen Pathways in the EU", in *CEPS Research Reports*, December 2021, https://www.ceps.eu/?p=34767.
34 Antonio Colmenar-Santos et al., "District Heating and Cogeneration in the EU-28: Current Situation, Potential and Proposed Energy Strategy for Its Generalisation", in *Renewable and Sustainable Energy Review*, Vol. 62 (September 2016), p. 621-639.

In particular, using power to produce hydrogen to blend in heating risks to be in contrast with the EU's efficiency objective of 32.5 per cent by 2030[35] (arguably to be raised in the context of the Green Deal and the Fit for 55 Package of 2021). It should also be considered that only 28 per cent of Italy's distribution grid is made of polyethylene pipelines, as opposed to 51 per cent in Germany and 70 per cent in France[36] – so that adopting hydrogen as a long-term option in the Italian distribution grid would require sizeable upfront investment.[37] Finally, the power generation sector can also help kickstarting demand. Italy's large gas share in power production (126.5 TWh in 2019, accounting for 44.6 per cent of Italy's power generation)[38] might provide a case for blending, although in consideration of the easy-to-abate nature of the power sector, even optimistic estimates attribute a minor role to hydrogen combustion for power generation (17-172 GWh by 2030).[39]

1.2 Supply side assets

The main clean hydrogen production routes currently considered are blue hydrogen or green hydrogen, and to a lesser extent to waste/biomass gasification (Table 1). As such, the access to abundant and cheap renewable electricity and to natural gas are the main supply-side assets to define a country's positioning in international hydrogen value chains. In this respect, Italy shows a mixed evidence.

RES endowment. Italy is the second EU country for renewable power generation after Germany. Italy's National Energy and Climate Plan (NECP) estimates RES-based (excluding hydropower) power generation to rise from 67.6 TWh (2019) to 114 TWh by 2030,[40] although such an estimation needs to be adjusted for the adoption of the 55 per cent emission reduction target at the EU level.

35 Nicola Armaroli and Andrea Barbieri, "The Hydrogen Dilemma in Italy's Energy Transition", in *Nature Italy*, 9 September 2021, https://www.nature.com/articles/d43978-021-00109-3.
36 FCH JU, *Opportunities for Hydrogen Energy Technologies Considering the National Energy and Climate Plans – Italy*, cit.
37 Ibid.
38 BP, *Statistical Review of World Energy 2020*, cit.
39 FCH JU, *Opportunities for Hydrogen Energy Technologies Considering the National Energy and Climate Plans – Italy*, cit.
40 Italy, *Integrated National Energy and Climate Plan*, December 2019, https://energy.ec.europa.eu/topics/energy-strategy/national-energy-and-climate-plans-necps_en#final-necps.

According to the EU's FCH Joint Undertaking estimations, covering Italy's 2030 clean hydrogen demand ranging between 113,100-571,800 tH_2 could require between 4.1 and 21 GW of dedicated renewable capacity.[41] Such a capacity would amount to 10.3-52.8 per cent of the additional variable RES installed capacity foreseen by 2030 according to Italy's NECP – although any scenarios could be mitigated by the use of surplus production of non-dedicated installations, blue hydrogen, and imports. The technical potential for variable renewable electricity generation is expected to be three times higher than the overall forecasted electricity consumption in 2030 – showing a superior proportion with respect to hydrogen-ambitious countries such as the Netherlands and Germany, while only 11 per cent of such a potential would be used by 2030 in contrast to 31 per cent in the Netherlands and 26 per cent in Germany, suggesting large margins to building up dedicated RES capacity to support green hydrogen production – lower however than Spain (5 per cent), France (6 per cent) or Portugal (8 per cent).[42] The cost of solar PV is lower than most of other European countries except Spain (Figure 4) – while the cost of onshore wind is comparable to France and Germany, although higher than Spain.[43] All in all, the country has the capacity to support domestically hydrogen demand expected by 2030 – at the condition of rapidly deploying additional, dedicated RES supply. A low RES target and a slow pace in new RES installations since 2012[44] are, to this extent, a factor of major concern for Italy's hydrogen ambitions.

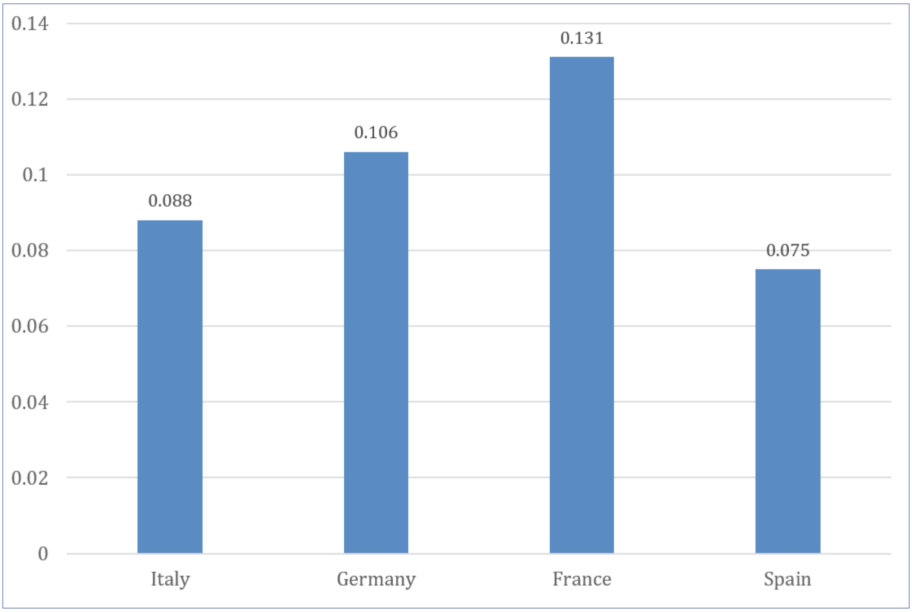
41 FCH JU, *Opportunities for Hydrogen Energy Technologies Considering the National Energy and Climate Plans – Italy*, cit. Based on Art.27.3 of Directive (EU) 2018/2001 (REDII), renewable fuels of non-biological origin (RFNBO) must abide to an additionality principle. The renewable energy installations used to generate electrofuels (including green hydrogen) must come into operation after or at the same time as the installation producing the RFNBO, and must not be connected to the grid or prove that electricity supplied to the RFNBO producing installation is not using electricity from the grid. European Parliament and Council of the European Union, *Directive (EU) 2018/2001 of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources*, http://data.europa.eu/eli/dir/2018/2001/oj.

42 FCH JU, *Opportunities for Hydrogen Energy Technologies Considering the National Energy and Climate Plans – Italy*, cit.

43 Weighted average levelised cost of energy (LCOE, measuring the average net present cost of electricity generation for a generating plant over its lifetime) for the non-household sector. IRENA, *Renewable Power Generation Costs in 2020*, Abu Dhabi, IRENA, June 2021, https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020.

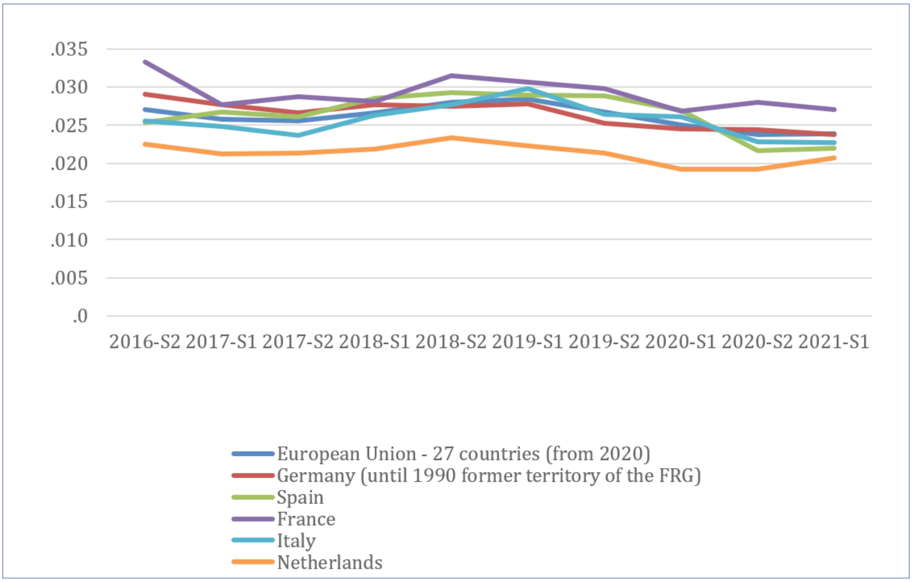
44 Between 2015 and 2020, Italy installed less than 2GW of wind capacity and 3GW of solar capacity. See Ember, "Italy", in *Global Electricity Review 2021*, March 2021, https://ember-climate.org/?p=38909.

Figure 4 | Weighted average LCOE, solar PV, commercial sector (US dollars/kWh)



Source: IRENA 2021.

Figure 5 | Gas prices (industrial consumers excluding taxes and levies, euro/kWh)



Source: Eurostat.

Gas and CCS. Italy is a large importer and consumer of natural gas. As Italy's energy system decarbonise, import capacity can be rendered available for imported gas to feed the domestic production of blue hydrogen. Yet, gas prices in Italy are in line with the EU average and not particularly competitive with respect to EU partners[45] (Figure 5) – let alone suppliers. As for the addition of CCS, Italy may have some locational advantage thanks to depleted oil and gas fields. However, capacity has its limits and blue hydrogen production might compete with other prospective CCS-reliant industrial processes to access storage sites. The only planned CCS facility in Italy – the Ravenna CCS hub – is expected to capture up to 5MtCO_2/year (Figure 6).[46] If (implausibly) used entirely for the production of blue hydrogen, the site could decarbonise about 620,000 tH_2[47] (up to 8 per cent of 2050 demand).[48] All in all, Italy's exposure to imported gas price volatility combined to constraints to CCS capacity suggest that the country could at best become an end consumer of imported blue hydrogen,[49] in case this technology ends up dominating the hydrogen value chains – as many assume for the short-to-medium term.[50] Finally, the potential of biomethane to blend with hydrogen for a possibly more long-term use should not be neglected – depending on alternatives and costs. Estimation of the technical potential of biomethane range for Italy between 2.7 and 8 bcm by 2030,[51] while the country is already the second largest EU producer of biogas.

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45 Eurostat database: *Gas Prices for Non-Household Consumers - Bi-annual Data (from 2007 onwards)*, https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_203&lang=en.

46 International Association of Oil & Gas Producers (IOGP), *Map of CCUS Projects in Europe*, November 2021, https://www.iogp.org/bookstore/?p=238561.

47 A highly efficient 90 per cent capture rate is assumed.

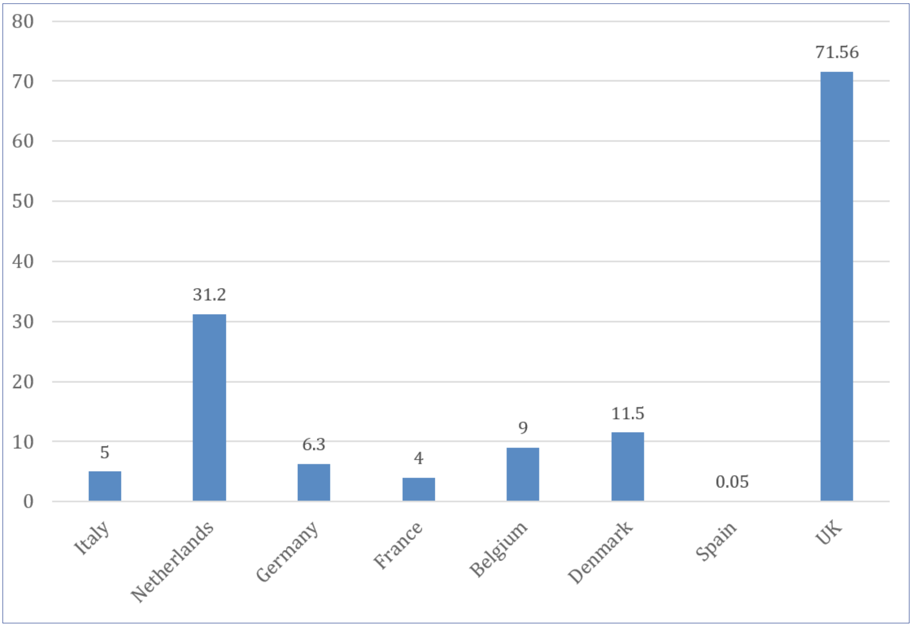
48 Own calculation on data from The European House - Ambrosetti, *H_2 Italy 2050. Una filiera nazionale dell'idrogeno per la crescita e la decarbonizzazione dell'Italia*, September 2020, https://www.snam.it/it/media/news_eventi/2020/H2_Italy_2050_Ambrosetti_Snam.html.

49 Jason Bordoff and Meghan L. O'Sullivan, "Green Upheaval", in *Foreign Affairs*, Vol. 101, No. 1 (January/February 2022), p. 68-84, https://www.foreignaffairs.com/node/1128122.

50 IEA, *The Future of Hydrogen*, cit.; IEA, *Global Hydrogen Review 2021*, cit.

51 Mieke Decorte et al., "Mapping the State of Play of Renewable Gases in Europe", in *REGATRACE Deliverables*, No. D6.1 (4 February 2020), https://www.regatrace.eu/wp-content/uploads/2020/02/REGATRACE-D6.1.pdf.

Figure 6 | CCUS planned facilities in Europe, November 2021 ($MtCO_2$/yr)



Source: IOGP.

Summing up, volumes foreseen by 2030 are likely to be supported by domestic supply. As for 2050, the Italian long-term strategy on GHG emissions reduction foresees to dedicate 110-170 TWh[52] (17.7-23.6 per cent of the foreseen power generation) to the production of 2.2-3.3 MtH_2, while an additional tH_2 could be delivered via biomass gasification+CCS.[53] In this respect, self-sufficiency would be guaranteed in a demand scenario focused on essential final uses, while expansive scenarios based on the use of hydrogen in additional final uses (light duty vehicles, power generation, and residential heating as suggested by Snam's projection of 23 per cent of final energy demand[54] – about 6.3MtH_2 – by 2050) may require imports for up to 2MtH_2.

52 Italy, *Strategia italiana di lungo termine sulla riduzione delle emissioni dei gas a effetto serra*, January 2021, https://ec.europa.eu/info/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-long-term-strategies_en#strategies.

53 Based on the assumption of about 10$MtCO_2$ annual capture capacity. Author's assumption is to be intended as purely illustrative and is not based on specific information. The only large ongoing CCS project at the moment in Italy aims at capturing 5$MtCO_2$/yr.

54 The European House - Ambrosetti, *H_2 Italy 2050*, cit.

1.3 Infrastructure

A hydrogen economy requires dedicated infrastructure. This includes pipelines for transporting hydrogen or hydrogen-based products, and different storage options including tanks and underground bulk storage for short term storage, or geological formations such as salt caverns, rock caverns, depleted gas fields or acquifer structures for longer-term, seasonal storage. A large and internationally interconnected infrastructure network constitutes together with demand development a typical first step to the buildup of an international hub, which should then be ideally followed by regulation ensuring third party access to hydrogen infrastructure, the emergence of structured trading rules such as standardised contracts, the entry of non-physical players, and finally the introduction of indexes used in physical contracts.[55] While hydrogen hubs are expected not to emerge before 30 years,[56] Italian actors have in multiple occasion mentioned the possibility and benefits of leveraging on Italy's gas infrastructure to support the ambition of becoming a regional hub for Europe.[57]

Italy's 32,700 km gas network is interconnected with a large number of foreign networks. According to Italy's gas transmission system operator (TSO) Snam, connectivity with North Africa could in particular reduce the cost of supply by 10-15 per cent with respect to national production.[58] Italy's infrastructural abundance fits into the European Hydrogen Backbone, a pan-European industry vision for the development of hydrogen transmission across Europe.[59] The backbone would expand from 6,800 km by 2030 to 23,000 km by 2040, comprising both retrofitted and repurposed gas infrastructure (75 per cent) and new pipeline stretches (25 per cent). According to such a scenario, the Transmed pipeline from Algeria would be upgraded to fully ship hydrogen[60]

55 Patrick Heather, "How a Traded Hydrogen Market Might Develop – Lessons from the Natural Gas Industry", in *Oxford Energy Forum*, No. 127 (May 2021), p. 31-36, https://www.oxfordenergy.org/?p=43719.

56 Ibid.

57 The European House - Ambrosetti, *H_2 Italy 2050*, cit.

58 Ibid.; Luca Franza, *Clean Molecules across the Mediterranean*, Rome, Istituto Affari Internazionali, April 2021, https://www.iai.it/en/node/13116.

59 Gas for Climate, *2020 European Hydrogen Backbone*, July 2020, https://gasforclimate2050.eu/?smd_process_download=1&download_id=471.

60 Gas for Climate, *Gas Decarbonisation Pathways 2020-2050*, April 2020, https://gasforclimate2050.

(ideally a 3.3 MtH_2 annual capacity),[61] while new dedicated hydrogen pipelines would be created in parallel to the cross-border interconnections at Passo Gries (TENP) and Tarvisio (TAG), allowing transit towards Austria and the North-West European industrial clusters.[62] Snam's take over of 49.9 per cent of the Tunisian and offshore section of Transmed from owner Eni is aimed at favouring "potential initiatives in the development of a hydrogen value chain from North Africa" according to the two Italian firms.[63] Solely based on pipe materials,[64] 98 per cent of the Italian gas grid would be ready for hydrogen shipping[65] – the same level of Spain and France, and larger than Germany (96 per cent). Full hydrogen-readiness requires however the readiness of all components (connections, valves, metering equipment, compressors – which marks a 24 per cent readiness in Europe according to distribution system operators),[66] for which sizeable investment is warranted. Still, an existing network is a key advantage, as central estimates on the cost of investment in transmissions locate the cost of repurposing at around one third of the cost of new hydrogen pipelines.[67]

While transit potential is significant, a limited availability of salt caverns for large-scale hydrogen storage with respect to the North-Western European countries remains a challenge fo Italy.[68] Some storage opportunities could however be identified in depleted fields in Emilia Romagna, also exploiting synergies with a high industrial density.[69] To this extent, Italy could more easily rely upon seasonal storage in the form of ammonia or liquid organic hydrogen

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eu/?smd_process_download=1&download_id=339.

61 Own calculation on data from ENTSOG, *Transmission Capacity Map 2021*, 5 November 2021, https://www.entsog.eu/maps#transmission-capacity-map-2021.

62 Gas for Climate, *2020 European Hydrogen Backbone*, cit.

63 Snam, *Eni and Snam Launch Partnership on Gas Pipelines between Algeria and Italy*, 27 November 2021, https://www.snam.it/en/Media/Press-releases/2021/Eni_Snam_pipelines_Algeria_Italy.html.

64 American Society of Mechanical Engineers (ASME), *B31.12 Hydrogen Piping and Pipelines*, 2019, https://www.asme.org/codes-standards/find-codes-standards/b31-12-hydrogen-piping-pipelines.

65 Snam, *Snam 2030 Vision and 2021-2025 Plan*, 29 November 2021, https://www.snam.it/en/Investor_Relations/Strategy/2021-2025_strategic_plan; Stefano Mauro, "Le reti gas esistenti sono pronte al trasporto dell'idrogeno", in *RiEnergia*, 27 April 2021, https://rienergia.staffettaonline.com/articolo/34753/Le+reti+gas+esistenti+sono+pronte+al+trasporto+dell'idrogeno/Mauro.

66 Ready4H2, *Europe's Local Hydrogen Network. Part 1: Local Gas Networks Are Getting Ready to Convert*, https://www.ready4h2.com/projects-3.

67 ACER, *Transporting Pure Hydrogen by Repurposing Existing Gas Infrastructure*, cit.

68 FCH JU, *Opportunities for Hydrogen Energy Technologies Considering the National Energy and Climate Plans – Italy*, cit.; IEA, *Global Hydrogen Review 2021*, cit.

69 Gas for Climate, *2020 European Hydrogen Backbone*, cit.

carriers (LOHC) – whose cost is however way higher than hydrogen storage in salt caverns – or in liquid or gaseous form in surface tanks or underground bulk storage facilities for short-term balancing.[70]

Under the promising perspective of the use of hydrogen or e-fuels in shipping and the emergence of a sea trade of clean ammonia and e-fuels, Italian harbours can also play as an important material asset. Refuelling facilities could be integrated with generation sites, the onshore transmission system and industrial clusters, helping Italian harbours to strengthen their position as logistical platforms in the Mediterranean.[71] In order for Italian ports to become import terminals, adequate infrastructure should be connected as the current connections based on roads and railroads are not fit for transporting large quantities of hydrogen.

1.4 Core and ancillary technologies

A country's presence in core and ancillary hydrogen technologies could play as an important factor of industrial centrality in an international hydrogen economy, regardless the specific level of hydrogen production or consumption at national level. Core technologies include electrolysers, CCS, and fuel cells. Italy is the second EU producer of electrolysis-related core technologies, with a 25.2 per cent share of total EU production in 2018.[72] Yet, Italy's electrolysers production is not aimed at producing large amounts of hydrogen. In case industry will be able to adapt, export opportunities might arise especially among partners willing to upscale green hydrogen production and holding a modest manufacturing base – notably in South America, Morocco, the Gulf or Australia. On carbon capture, Italy does not host operating facilities – in contrast to Germany or the UK. Italy hosts one of the 24 current CCUS projects in Europe, the abovementioned Ravenna CCS Hub by Eni.[73] While activities are limited in Italy, Eni also works on CCUS abroad – notably in the UK and the UAE, with a view to develop carbon capture also in Libya, Australia and Timor. Fuel

70 Gniewomir Flis and Matthias Deutsch, *12 Insights on Hydrogen*, Agora Energiewende January 2022, https://www.agora-energiewende.de/en/publications/12-insights-on-hydrogen-publication.

71 SRM and ESL@Energy Center, *MED & Italian Energy Report 2021*, December 2021.

72 The European House - Ambrosetti, *H_2 Italy 2050*, cit.

73 IOGP, *Map of CCUS Projects in Europe*, cit.

cells production is not particularly developed in Italy, amounting to about 1 million euro in 2018 compared to Germany's 21.8 million.[74] The picture is more promising with respect to some ancillary technologies, grouped in different clusters: mechanical, thermal, feedstock, electric, and control systems.[75] Italy is the leading manufacturer in hydrogen-related thermal technologies (evaporators, condensers, burners, boilers equipment) in Europe, with a market share of 24.4 per cent of total EU production and a 20.5 per cent export/production ratio in 2018.[76] As for mechanical technologies (valves, pumps, compressors and pressure converters) Italy ranks second in Europe behind Germany, with a 19.3 per cent market share. A weaker position is detected as for electrical technologies (notably wind turbines and solar panels), where Italy is a net importer – especially from China; and control system technologies. In any case, it needs to be acknowledged that the generally small size of Italy's actors in these industries may play as a disadvantage with respect to the key competitors (mainly Germany, China, Japan and Korea).

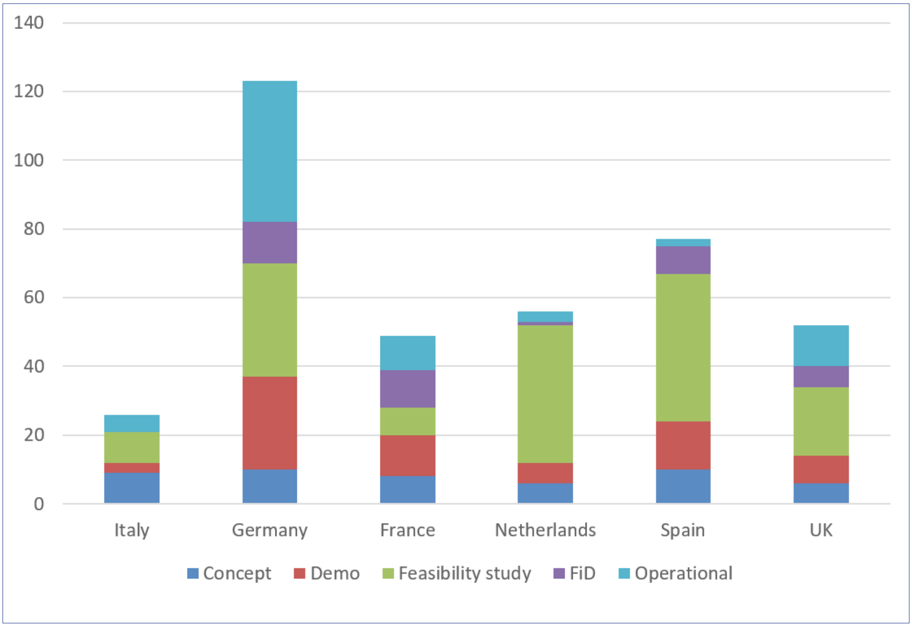
1.5 Actors and initiatives

The presence of key industrial actors is an important asset for the development of hydrogen clusters and later on enhanced international connectivity. Especially in the energy sector, Italian actors look at hydrogen's future role in positive terms. Italy counts 25 projects at different stages of development (Figure 7) for a cumulated capacity of 305,300 tH_2/y.[77] However, despite the dynamism of large energy players and synergies developed around current and prospective "hydrogen valleys",[78] Italy is currently lagging behind in terms

74 The European House - Ambrosetti, *H_2 Italy 2050*, cit.
75 Ibid.; Confindustria, *Piano d'azione per l'idrogeno*, cit.
76 The European House - Ambrosetti, *H_2 Italy 2050*, cit.
77 As a lot of dynamism is detected in the launch of new projects, the data provided might be soon outdated. For a real-time assessment of projects, database of the IEA (https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database) and the EU's Clean Hydrogen Alliance (https://europa.eu/!3rnvY7) are frequently updated.
78 Hydrogen Valleys refer to pilot projects integrating different sections of the hydrogen value chains. These initiatives are supported under the Mission Innovation's Hydrogen Valley Platform and the FCH JU, with the financial contribution of EU research funding (for a summary of hydrogen valleys developed under Mission Innovation, see the Hydrogen Valleys Platform: https://www.h2v.eu/hydrogen-valleys). A hydrogen valley is currently developed in South Tirol integrating sourcing, production, storage, transport, distribution and mobility, aimed at decarbonizing the mobility sector and connecting with

of the number of current projects and associated volumes with respect to European partners (Figure 7).

Figure 7 | Number of hydrogen projects, October 2021

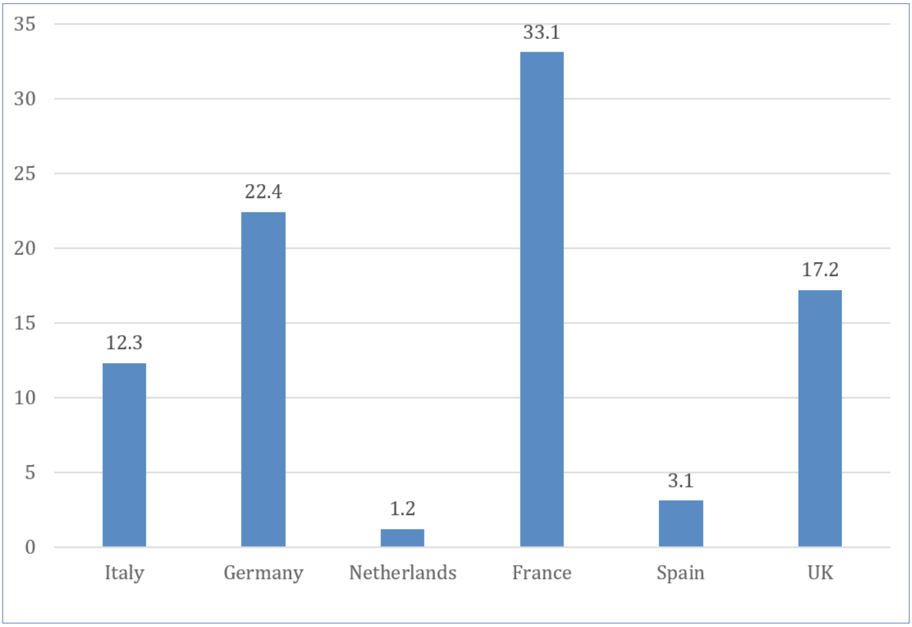


Source: IEA Hydrogen project database.

Some gap is also detected with respect to R&D expenditure, where Italy lags behind frontrunners such as France, Germany and the UK (Figure 8) – although some catching up could be expected in the near future in light of the contribution of the National Plan of Recovery and Resilience (PNRR, see the next section).

the Brennero infrastructural axis (https://www.h2v.eu/hydrogen-valleys?populate=&field_ch_1_q_10_value=IT). Further initiatives are coming in other Italian regions. See for a summary: Paolo Deiana, Stephen McPhail and Giulia Monteleone, "Enea Hydrogen Valley, towards an Infrastructural Hub in Italy", in *Energia, ambiente e innovazione*, No. 1/2021 (January-April 2021), p. 144-147, https://doi.org/10.12910/EAI2021-029.

Figure 8 | R&D expenditure in hydrogen and fuel cells
(annual average 2013-2017, million euro)



Source: FCH JU, *Opportunities for Hydrogen Energy Technologies Considering the National Energy and Climate Plans – Italy*, cit.

1.6 Foreign partnerships

Finally, what foreign partnerships are likely to define Italy's future role in the international hydrogen value chains? It is relatively consensual to assume that international hydrogen partnerships are set to develop in concentric – although not mutually exclusive – circles. A first circle of Italy's neighbours can be physically interconnected to trade gaseous hydrogen via pipelines. A second circle refers to more distant producers, that can however provide hydrogen-based liquid products such as ammonia, LOHC and e-fuels via maritime transport. Finally, a third group of actors shows export potential, but low technological capacities. This group can offer opportunities for Italian actors to both invest in local production and to export hydrogen-related technologies. Specific conditions can help identifying the Italy's prospective partners in hydrogen value chains. These include: first, the local hydrogen potential, as defined by local RES deployment costs, abundance of natural gas reserves, natural storage sites for both hydrogen and carbon. Second, infrastructure connectivity. Ideally, partners should be already linked to Italy through gas infrastructure networks. Third, belonging to a common regulatory or economic space. Such a condition would help de-risking investments by reducing the potential politicisation of hydrogen trading – a risk particularly concrete when considering hydrogen's affinity to gas' technology and logistics. Finally, existing energy partnerships and trade relations. The largest the penetration of Italian prospective hydrogen actors, the more significant the rationale to develop a partnership on hydrogen.

As a first circle, the North African region could be seen as a natural future hydrogen partner for Italy. As a region with the lowest-cost RES deployment (with bidding prices for wind energy stand at 0.03 euro/kWh and solar energy at 0.05 euro/kWh), abundance of natural gas reserves in Algeria, Libya and Egypt, infrastructural connectivity to Italy through the Transmed and Greenstream pipelines, and dense existing trade and energy relations accompanied by a large presence of Italian economic actors, the region presents unique opportunities to produce low-cost hydrogen and support the decarbonisation of Italy and the EU.[79] In particular, a study suggested that in case of high hydrogen demand (about 25 per cent of final energy consumption) in the Mediterranean region, an integrated approach would require 36 GW less of installed RES capacity with respect to a situation where the two shores develop hydrogen supply in insulation from each other.[80]

In the Eastern neighbourhood, a promising hydrogen partner for Italy and Italian actors could be Ukraine. With a large network of gas pipelines (about 90 bcm of current export capacity to the EU) expected to be left idle by Russia's diversion of gas flows through the Nord Stream and Turk Stream corridors and large gas storage facilities, the country needs to re-invent the future of

79 For a more detailed analysis on hydrogen integration in the Mediterranean, see Luca Franza, *Clean Molecules across the Mediterranean*, cit.; Gonzalo Escribano, "H2 Med: Hydrogen's Geo-Economic and Geopolitical Drivers and Barriers in the Mediterranean", in *Elcano Policy Papers*, May 2021, https://www.realinstitutoelcano.org/en/policy-paper/borrador-automaticoh2-med-hydrogens-geo-economic-and-geopolitical-drivers-and-barriers-in-the-mediterranean.

80 SRM and ESL@Energy Center, *MED & Italian Energy Report 2021*, cit.

its energy connectivity with Europe. While local gas production stagnates and wind potential is largely unexploited, there is room for growth in case blue hydrogen could provide a rationale for the exploitation of Black Sea gas resources and the country ramps up investment in RES. Another advantage for a hydrogen partnership lies in Ukraine's integration into the regulatory space of the Energy Community Treaty. Ukraine may either provide clean hydrogen to Italy's market or become an outlet for Italian actors' investment in clean hydrogen capacity and exporters of ancillary technologies. Yet, in contrast to North Africa, a partnership with Ukraine or other eastern neighbours would not contribute to Italy's prospective centrality in regional transmission, as they would be already connected to core demand centres of North-West Europe.

Outside the neighbourhood, opportunities for cooperation in hydrogen technologies can be found in the Gulf. In particular, the United Arab Emirates have launched a Hydrogen Leadership Roadmap aiming at making the country a large exporter of hydrogen, H-DRI steel and e-kerosene. While the strategy identified as key export markets Germany, South Korea, Japan and India, Italy's Eni is well positioned in the country thanks to its strategic partnership with UAE's Mubadala Fund on – among other topics – hydrogen and CCS. Especially here and other Gulf countries Italian firms can find a promising market for ancillary thermal and mechanical technologies, potentially offering a complement to the likely penetration of German and Asian core hydrogen technologies across the Gulf region. South America is characterised by a high renewable energy penetration. Chile and Argentina in particular have been showing ambition with respect to the export of green hydrogen, although considering distances are more likely to supply customers in North America or Asia. Benefitting from an oversupplied power market and having reached its RES target five years ahead of schedule, Chile plans to install 25 GW of electrolysers by 2030 and be one of the top three green hydrogen exporters by 2040, aiming at a future potential for 160 MtH_2 of annual production. In this context, Italian actors can profit from a large established presence in Latin America's countries' RES sector to develop the production of green hydrogen and the export of ancillary technologies. Enel Green Power (EGP) has 150 plants across the continent, for a total installed renewable energy capacity of 15.3 GW. In Chile, EGP is developing an industrial scale green hydrogen plant in Punta Arenas. While this is the only Italian hydrogen project in South America at the moment, EGP and Enel are largely present in the continent's energy sector. Other potential markets for

Italy's export of hydrogen-related technologies could be Australia, the US or Canada.

2. Enabling frameworks

Beside material assets, enabling frameworks are an essential condition for countries to become early movers and conquering position in the hydrogen value chains. Governance frameworks can provide guidance and signals to actors, set rules to facilitate collective action, offer means for implementation (such as financial resources, technology and capacity building), and promote knowledge and learning.[81] This section takes stock of enabling institutional frameworks for Italy to de-risk early moves in emerging hydrogen value chains, identifying a national, European and global dimension.

2.1 Italy's domestic framework: From the NECP to the recovery plan

Italy's National Energy and Climate Plan (NECP)[82] recognises the role of (especially green) hydrogen mentioning power-to-gas (P2G) technologies as an option for the long term storage of renewable electricity, emphasising the role of existing technologies and infrastructure endowments and the positive impact of alternative gases in improving Italy's supply diversity.[83] While the NECP looks at different possibilities – including blending as a transitional step to the development of two parallel infrastructures (for gas and hydrogen), the only specific target concerns the transport sector. The NECP suggests that hydrogen will provide 1 per cent of the RES target for transport, amounting to about 21,132 tH_2. Within this amount, the NECP suggests that 80 per cent

81 Sebastian Oberthür, Gauri Khandekar and Tomas Wyns, "Global Governance for the Decarbonization of Energy-Intensive Industries: Great Potential Underexploited", in *Earth System Governance*, Vol. 8 (June 2021), Article 100072, https://doi.org/10.1016/j.esg.2020.100072.

82 NECP are 10-years integrated national energy and climate plans adopted by EU member states for the period 2021-2030 under the Regulation (EU) 2018/1999. See European Parliament and Council of the European Union, *Regulation (EU) 2018/1999 of 11 December 2018 on the Governance of the Energy Union and Climate Action*, http://data.europa.eu/eli/reg/2018/1999/oj.

83 Italy, *Integrated National Energy and Climate Plan*, cit.

could be injected in the existing grid subject to previous methanation, while only 20 per cent would be used in pure form for bus and trains. To this extent, Italy transposed the Alternative Fuel Infrastructure Directive (AFID) 94/2014,[84] committing to realise refueling points – without however specific financial commitments. The legislation also foresees the possibility of three-year updates of the National Strategic Framework – or in case of significant technological developments or new market conditions or social and environmental priorities. This flexible design is of particular significance in the context of the legislative review at EU level driven by the adoption of the 55 per cent emissions reduction target at EU level. It is however clear that in this light the whole NECP ambitions with respect to hydrogen will have to be revised upwards.

Such a reconsideration for the role of hydrogen has already provisionally taken place with the preliminary guidelines for a national hydrogen strategy issued by the Ministry for the Economic Development.[85] The government has the objective of covering with hydrogen 2 per cent of the final energy consumption by 2030, amounting to about 700,000 tH_2 per year – and up to 20 per cent by 2050. These would be delivered by 5GW of electrolyser capacity – which would however cover up slightly more than half the said amount, suggesting a role for blue hydrogen as well. Sectoral objectives are however only foreseen for long haul trucks – respectively 2 per cent by 2030 and up to 80 per cent by 2050. According to the guidelines, these targets require up to 10 billion euro between 2020 and 2030, to which one should add investment for dedicated RES capacity (to deliver 37-40TWh of dedicated renewable electricity by 2030 if hydrogen will be entirely delivered through electrolysis). Out of the total amount, 5-7 billion euro would be dedicated to production, 2-3 billion euro to distribution infrastructure, and 1 billion euro to R&D.

A first step in such a direction is in Italy's National Recovery and Resilience Plan (PNRR), which allocates 3.19 billion euro to hydrogen. In particular, Italy will be spending 2 billion euro for the use of hydrogen in hard-to-abate sectors,

84 Legislative decree No. 257 of 16 December 2016: *Realizzazione di una infrastruttura per i combustibili alternativi* (Deployment of alternative fuels infrastructure), https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:decreto.legislativo:2016;257.

85 Italian Ministry of Economic Development, *Strategia nazionale idrogeno. Linee guida preliminari*, 2020, https://www.mise.gov.it/images/stories/documenti/Strategia_Nazionale_Idrogeno_Linee_guida_preliminari_nov20.pdf.

0.23 and 0.30 in experimentation for road transport and rails, 0.50 for hydrogen production, and 0.16 for R&D[86] – an allocation in line with what is foreseen by the plans of other large European countries – but significantly lower than the overall resources that France and Germany intend to allocate to the pursuit of their hydrogen strategies (respectively 8.2 and 10.3 billion euro for this decade).

2.2 The role of the EU

Without coordination with other EU member states and with the EU, Italy's chances of competing globally are slim. As a provider of political and financial support, a regulatory powerhouse, a large and interconnected market, the EU context offers the most sophisticated framework to experiment the cross-border integration of hydrogen value chains.

Political support and guidance. The Hydrogen Strategy sets a target of 40 GW of electrolysers to be installed within the EU by 2030. and additional 40 GW to be installed in the southern and eastern EU neighbourhood. This implies coordination to align investments in renewable energy installations, gas pipeline conversion (or construction of dedicated hydrogen lines) and end-user markets – to make sure that the timing of supply and demand creation is synchronised. Yet, while clear on targets, the EU strategy provides limited details with respect to implementation.[87] As a complement, other EU strategies may provide a positive political signaling for regional hydrogen integration, ranging from internal strategies such as the Energy System Integration Strategy[88] and the 2020 Industrial Strategy[89] to external initiatives concerning the neighbourhood and the Global Gateway initiative,[90] streamlining 300

86 Italy, *Piano nazionale di ripresa e resilienza*, May 2021, https://www.governo.it/en/node/17027.

87 Nicola De Blasio and Alejandro Nuñez-Jimenez, "The European Union at a Crossroads: Unlocking Renewable Hydrogen's Potential", in *Belfer Center Briefs*, November 2021, https://www.belfercenter.org/node/135744.

88 European Commission, *Powering a Climate-Neutral Economy: An EU Strategy for Energy System Integration* (COM/2020/299), 8 July 2020, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0299.

89 European Commission, *Updating the 2020 New Industrial Strategy: Building a Stronger Single Market for Europe's Recovery* (COM/2021/350), 5 May 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0350.

90 European Commission and High Representative of the Union, *The Global Gateway* (JOIN/2021/30), 1 December 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021JC0030.

billion euro in connectivity objectives including clean technology exchanges and clean energy supply security.

Funding. As for funding, the Commission assumes that the introduction of 40 GW of electrolysers capacity by 2030 and 500 GW by 2050 would require between 180-470 billion euro in hydrogen production capacity, to which one should add transport infrastructure, industry retrofitting, and refueling stations in the road transport sector, depending on hydrogen's role in final energy consumption sectoral mix. Instruments include: i) the Important Projects of Common European Interest (IPCEI).[91] The IPCEI status allows for a more extensive use of state aid, and is particularly fit to support hydrogen technologies due to their focus on upscaling pilot facilities;[92] ii) Structural funds such as the European Regional Development Fund (ERDF) and the Cohesion Fund (CF), with the option to foresee also interventions from the Just Transition Mechanism (17.5 billion euro from the Multiannual Framework Programme and Next Generation EU, plus additional pillars to be supported by InvestEU and the European Investment Bank loans) for investment in hydrogen clusters in coal regions in decline; iii) Financial support to infrastructure policy, by way of the Connecting Europe Facility (CEF) amounting to about 5.6 billion euro over the 2021-2027 budget cycle; iv) the recovery instruments NextGeneration EU and Invest EU; v) Horizon Europe to support research in the areas of generation, infrastructure, and end-use applications; vi) and the ETS Innovation Fund – based on the revenues of the EU emission trading system. Out of seven large-scale projects selected for a grant under the ETS Innovation Fund, two are dedicated to steel (in Sweden) and refining (in Finland) transition to clean hydrogen.[93] Of critical importance for funding, hydrogen was included in the first Delegated Act[94] of

91 IPCEIs must address market failures and contribute to the EU strategic objectives, involve several EU countries, involve private finance, and generate positive spillovers.

92 Art. 107(3b) TFEU; European Commission, *Criteria for the Analysis of the Compatibility with the Internal Market of State Aid to Promote the Execution of Important Projects of Common European Interest* (C/2021/8481), 25 November 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM:C(2021)8481. At the time of writing, EU member states had submitted lists of hydrogen projects to participate to a "matchmaking" – after which projects can obtain an IPCEI status.

93 European Commission, *First Call for Large-Scale Projects. List of Proposals Pre-Selected for a Grant*, 16 November 2021, https://ec.europa.eu/clima/document/download/3fbddce1-4dbb-418b-861d-45d20a7a5a67_en.

94 European Commission, *Delegated Regulation (EU) …/... supplementing Regulation (EU) 2020/852…* (C/2021/2800), 4 June 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=PI_COM:C(2021)2800.

the EU sustainable finance taxonomy,[95] which sets criteria for investments to be considered "sustainable" in order to guide them towards the objectives of the European Green Deal. Overall, the sustainable finance framework is supportive for hydrogen technologies. The emissions threshold for hydrogen production was set at $3tCO_2e/tH_2$ on a lifecycle basis, which favours green hydrogen but does not rule out fossil-based forms. Similarly, ammonia and hydrogen-based fuels are included, based on criteria applied to biofuels under the renewable energy directive (REDII)[96] – which sets the emissions threshold to $94gCO_2e/MJ$. Finally, manufacturing of all hydrogen-related machines (electrolysers as well as machines for blue or turquoise hydrogen) is also included.

Regulatory support. Several EU regulatory instruments constitute a key enabler for a transnational hydrogen economy. Within the framework of the Fit for 55 Package, the European Commission proposed a revision of the Alternative Fuel Infrastructure Directive mandating the deployment of gaseous hydrogen refueling infrastructure with a maximum 150 km distance in-between them along the Trans-European Network-Transport (TEN-T) core, and 450 km distance for liquid hydrogen.[97] The deployment of hydrogen in the transport sector is also set to benefit from the proposal to extend carbon pricing to the transport and building sectors. In 2021, the European Commission presented a package of regulatory proposals[98] to support the shift from natural gas to renewable and low-carbon gases, including hydrogen. The proposal foresees that national network development plans and the EU-wide ten-year network development plan (TYNDP) are based on a joint scenario for gas, electricity and hydrogen in order to favour the integration of electricity and gas grids. Second, tt introduces a European Network for Network Operators of Hydrogen (ENNOH), to be added to the existing ones for electricity (ENTSOE) and gas (ENTSOG). Third, it makes

95 European Parliament and Council of the European Union, *Regulation (EU) 2020/852 of 18 June 2020 on the Establishment of a Framework to Facilitate Sustainable Investment…*, http://data.europa.eu/eli/reg/2020/852/oj.

96 Art. 25(2) of Directive (EU) 2018/2001.

97 Art. 6, European Commission, *Proposal for a Regulation on the Deployment of Alternative Fuels Infrastructure...* (COM/2021/559), 14 July 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0559.

98 European Commission, *Proposal for a Directive on Common Rules for the Internal Markets in Renewable and Natural Gases and in Hydrogen* (COM/2021/803), 15 December 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0803; European Commission, *Proposal for a Regulation on the Internal Markets for Renewable and Natural Gases and for Hydrogen* (COM/2021/804), 15 December 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0804.

mandatory the acceptance of up to 5 per cent hydrogen blending at cross-border interconnection points. Finally, the package introduces a certification of renewable and lo-carbon gases to ensure Guarantees of Origin. Such a scheme adds hydrogen to the family of Guarantees of Origin already in use for electricity producers to sell renewable electricity at a premium to consumers that need to validate claims about carbon reduction or neutrality.[99] Currently, an EU-wide voluntary certification scheme (CertifHy)[100] is in place. At the same time, the EU co-legislator reached an agreement[101] on the Commission proposal to reform the TEN-E framework,[102] which could become instrumental to the EU gas industry vision of the abovementioned "hydrogen backbone" for Europe.[103]

Protection. As the transition towards a hydrogen economy for key lead sectors such as EIIs takes place in an internationally competitive environment, it is critical for first movers to rely upon some form of protection. To this extent, the Carbon Border Adjustment Mechanism (CBAM) proposed by the European Commission in the Fit for 55 Package presented in July 2021 can play an important role.[104] CBAM would impose on importers an additional duty corresponding to the carbon price that would have been paid, had the goods been produced under the EU's carbon pricing rules. To this extent, the mechanism is expected to reduce risks related to the competitive pressures for trade-exposed sectors transitioning towards clean hydrogen. As such, CBAM could encourage demand kickstart directly in hard-to-abate sectors, with no need to use sectors with easier alternatives for the only sake of market creation. Also, by covering nitrogen-based fertilisers produced through natural gas-based ammonia, CBAM could incentivise Italy's prospective hydrogen partners (i.e. Algeria) towards decarbonising ammonia production to preserve access to

99 Nikolaus J. Kurmayer, "EU Plans Single Database to Certify Carbon Content of Hydrogen, Low-Carbon Fuels", in *Euractiv*, 18 November 2021, https://www.euractiv.com/?p=1666588.

100 See official website: https://www.certifhy.eu.

101 European Parliament and Council of the European Union, *Provisional Political Agreement of the Council and the Parliament on Guidelines for Trans-European Energy Infrastructure*, 17 December 2021, https://data.consilium.europa.eu/doc/document/ST-15036-2021-INIT/en/pdf.

102 European Commission, *Proposal for a Regulation on Guidelines for Trans-European Energy Infrastructure*… (COM/2020/824), 15 December 2020, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020PC0824.

103 Gas for Climate, *2020 European Hydrogen Backbone*, cit.

104 European Commission, *'Fit for 55': Delivering the EU's 2030 Climate Target on the Way to Climate Neutrality* (COM/2021/550), 14 July 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0550.

the EU market, therefore unleashing local (blue and green) hydrogen potential.

Structured partnerships. Public-private partnerships existed under the EU premises since 2008, with the establishment of the Fuel Cell and Hydrogen Joint Undertaking funded under EU research instruments. Similarly to batteries and critical raw materials, the EU established a Clean Hydrogen Alliance bringing together industry leaders, governments and civil society to "build up an investment pipeline for scaled-up production" and demand for clean hydrogen in the EU.[105] Finally, building on existing joint undertakings, the Commission proposed ion 2021 a Clean Hydrogen Partnership as one of 10 strategic public-private partnerships between the EU, member states and the industry.[106] The gradual upgrading of these initiatives identifies a will to revise the EU's traditionally limited industrial policy actorness, and to consolidate an industrial leadership in a sector of the energy transition considered still "contestable" and where the EU holds some competitive advantage.

External instruments. The EU's engagement with its neighbourhood on clean energy is not new. Yet, for a long time it brought little results. A decoupling between an energy diplomacy concentrated on gas supply and climate priorities,[107] local elites' entrenchment with fossil fuel interests and rents, and the adoption of a regional approach in a neighbourhood context affected by poor regional integration[108] are considered as reason for unsuccess. However, climate prioritisation stemming from the European Green Deal may bring elements of innovation in the EU's neighbourhood policy. The first priority of the EU's Renewed partnership with the Southern Neighbourhood is the "massive deployment of renewable energy and clean energy production, contributing to the aspiration to have at least 40 GW or electrolysers capacity in the EU Neighbourhood by 2030".[109] The new Neighbourhood, Development and

105 European Commission website: *European Clean Hydrogen Alliance*, https://europa.eu/!GfQW9G.

106 European Commission, *Proposal for a Council Regulation Establishing the Joint Undertakings under Horizon Europe* (COM/2021/87), 23 February 2021, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021PC0087.

107 Anna Herranz-Surrallés, "The Green Transition. A New and Shared Paradigm in the EU Partnership with the Southern Neighbourhood?", in *IEMed Mediterranean Yearbook 2021*, p. 24-31, https://www.iemed.org/?p=63740.

108 Simone Tagliapietra, *Energy Relations in the Euro-Mediterranean. A Political Economy Perspective*, Cham, Palgrave Macmillan, 2017.

109 European Commission, *Renewed Partnership with the Southern Neighbourhood. A New Agenda for the Mediterranean* (JOIN/2021/2), 9 February 2021, https://eur-lex.europa.eu/legal-content/EN/

International Cooperation Instrument (NDICI) will increase overall assistance to the neighbourhood from 17 billion euro (2014-2020) to 22 billion (2021-2027), out of which one quarter will support climate objectives. "Sustainable growth" also features among the priorities of the external investment facility, through the European Fund for Sustainable Development (EFSD+) and the External Action Guarantee (EAG). These resources could help covering an identified investment gap of 16 billion US dollars a year for the Southern Mediterranean to achieve their 2030 renewable energy targets.[110]

2.3 The multilateral level

Beside initiatives of bilateral and regional coordination, international institutions providing guidance and predictability can constitute an important enabling framework.

Technical dialogue and scientific cooperation. The IEA and the IRENA constitute relevant platforms for international dialogue on hydrogen, mainly offering analyses and providing recommendations to their members for the upscale and uptake of hydrogen technologies. Under the Clean Energy Ministerial (CEM),[111] a hydrogen Initiative drives collaboration to accelerate the commercial deployment of hydrogen fuel cells technologies. Under Mission Innovation,[112] a "Clean Hydrogen Mission" was launched in 2021 to increase the cost-competitiveness of clean hydrogen by reducing end-to-end costs to 2 US dollars/kgH_2 by 2030. The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) was launched by the US Department of Energy in 2003 to foster cooperation on R&D, common codes and standards, and information sharing on infrastructure development among 22 partners. Finally, the largest private sector dialogue initiative is the Hydrogen Council, gathering together more than 120 large corporations from various sectors to promote the scaling

TXT/?uri=CELEX:52021JC0002.

110 IEA, *Clean Energy Transitions in North Africa*, October 2020, https://www.iea.org/reports/clean-energy-transitions-in-north-africa.

111 The Clean Energy Ministerial (CEM) brings together ministers with responsibility for clean energy technologies from the world's major economies, and ministers from selected states that are leading in various areas of clean energy.

112 Mission Innovation is a multilateral initiative of 22 countries to catalyse investment in research, development and demonstration to enhance affordability and accessibility of clean energy.

up of hydrogen solutions.[113] In this respect, seven large hydrogen projects developers – including Italy's Snam – have launched the Green Hydrogen Catapult initiative, aimed at installing 25 GW of green hydrogen production capacity by 2026, with a view to take the cost of green hydrogen below 2 US dollars/kgH_2.[114]

Standards. The development of hydrogen value chains will require harmonised approaches, standards and certificates for H_2-based fuels and chemical products. There are currently 33 standards for hydrogen technologies published or under development under the International Organization for Standardization (ISO/TC 197), concerning liquid hydrogen (fuel tanks and fuelling systems interface), fuel quality (product specification), generators (safety and test methods for performance), gaseous hydrogen (refueling devices, fuelling stations, land vehicle containers, stationary storage, fuelling protocols), and hydrogen generators using water electrolysis. Notably, most standards currently published or under development concern applications in the transport sector and date from 2018 onwards, reflecting a growing trend in standardisation of hydrogen technologies.

International industrial decarbonisation clubs. Notably, at the COP26 the EU and the US decided to end a long-standing trade dispute on steel and aluminium, including a strong green dimension.[115] The parts intend to negotiate some form of carbon content standard on steel imports, and to form a technical working group to define methodologies for calculating steel and aluminum carbon-intensity. Previously, a "Green Alliance" was signed between the EU and Japan, aimed at cooperating on research in clean energy technologies including hydrogen, and supporting an international rules-based system for the international governance of decarbonisation processes.[116] Sectoral "climate clubs" may provide a platform to i) mitigate the impact of internationally controversial EU measures such as CBAM on the EU's like-minded partners and

113 Hydrogen Council, *Hydrogen Council Adds Fourteen New Members Including Bankers, Engineers, Industrials and Energy Companies, Confirming Wide-Ranging Interest in Hydrogen*, 12 July 2021, https://hydrogencouncil.com/en/?p=4808.

114 Green Hydrogen Catapult website: https://greenh2catapult.com.

115 Uri Dadush, "What to Make of the EU-US Deal on Steel and Aluminium?", in *Bruegel Blog*, 4 November 2021, https://www.bruegel.org/?p=45643.

116 EU and Japan, *Towards a Green Alliance to Protect Our Environment, Stop Climate Change and Achieve Green Growth*, 27 May 2021, https://europa.eu/!Jk86Uk.

reduce diplomatic backlash, ii) control standardisation processes, and iii) add pressure on non-members such as China to scale up industry's decarbonisation in order not to be left behind, while creating enforcement mechanisms to deter club's member from deviate from their climate commitments.[117]

International carbon markets. Carbon market mechanisms can create incentives for Italy's identified partners that lack appropriate frameworks to kickstart the deployment of hydrogen technologies. Carbon market instruments revolve around the Art. 6 mechanisms under the Paris Agreement, whose implementation rulebook was agreed during the CoP26. Under art. 6.2, the Agreement foresees cooperative approaches based on the transfer of internationally traded mitigation outcomes (ITMOs) on a bilateral or multilateral basis. Such a mechanism is sufficiently flexible to allow the tailor-made approach that would be needed due to the complexity of hydrogen technologies. Partners could therefore focus on activities aimed at establishing an import-export relation for the long term, designing cooperation activities around technology transfer, support to infrastructure investment, lead market creation, regulatory upgrades and border taxation design. Japan and Saudi Arabia are already cooperating under the Joint Crediting Mechanism for bilateral collaboration on GHG mitigation.[118] Such a scheme could constitute a blueprint for others' – including Italy – to consider.

3. Taking stock of the challenges

While Italy shows interesting assets that would allow the country to play a potentially central role in a regional hydrogen economy, and enabling frameworks are aligning, some factors may challenge Italy's potential international hydrogen status and require attention.

117 William Nordhaus, "Climate Clubs: Overcoming Free-Riding in International Climate Policy", in *American Economic Review*, Vol. 105, No. 4 (April 2015), p.1339-1370, https://doi.org/10.1257/aer.15000001; Guntram B. Wolff, "Europe Should Promote a Climate Club after the US Election", in *Bruegel Opinions*, 10 December 2020. https://www.bruegel.org/?p=40278.

118 Axel Michaelowa et al., "Promoting Carbon-Neutral Hydrogen through UNFCCC and National-Level Policies", in *T20 Saudi Arabia Policy Briefs*, September 2020, https://www.g20-insights.org/?p=15270.

Leadership and political guidance. There are concerning signals that Italy is not perceived as a leader in the hydrogen race. A recent Bloomberg report sponsored by Hyundai[119] aimed at measuring different countries' "hydrogen leadership" – while the analysis includes Italy's major European peers (Germany, France, the UK, the Netherlands), Italy does not feature in the top 15. While sponsored reports should be taken with some caution, it is worth signaling that the methodology adopted considers several indicators that are problematic to Italy – namely regulatory support, the level of experimentation of hydrogen technologies, and intergovernmental import-export cooperation agreements. In fact, Italy lacks an ad hoc legislation that could discipline the authorisation of green hydrogen production plants, and there are no instruments yet to support P2G installations. As seen, experimentation lags behind other European countries, while a proper hydrogen diplomacy is yet to be developed. This latter aspect marks a contrast with diplomatic activity of Germany, Japan, South Korea, or the Netherlands towards prospective suppliers such as Australia, the Gulf, Norway or African countries. Delays on these multiple fronts risk producing negative signals for investors and third countries. Beside specific drawbacks, Italy is at the time of writing a latecomer with its hydrogen strategy, whose embryonic document lacks the detailed and systematic industrial approach offered by some other national strategies.

Misguided focus. A sector-specific approach, not integrated into a broader industrial policy vision, risks turning hydrogen into an end in itself instead of a means to achieve deep decarbonisation. In light of deep uncertainty with respect to hydrogen technologies' future competitiveness and pick up in final uses, articulating support policies around narrow objectives such as i.e. the pursuit of a regional hub status carries risks of asset stranding or technological and carbon lock ins. The experience of natural gas in Italy demonstrates that while infrastructural abundance and external connectivity brought advantages, it did not translate in itself into the achievement of a regional hub status. With respect to gas, Italy remains a peripheral end-user suffering from high costs that only recently provided signals of closing the gap with respect to other European economies. The gas network may certainly allow hydrogen to make a relatively easy inroad into Italy's economy – but it is necessary for the grid

119 Bloomberg website: *The H2 Economy. Investing in a Hydrogen-powered Future*, https://sponsored.bloomberg.com/immersive/hyundai/the-h2-economy.

to adapt to the needs of hydrogen-consuming industries, instead of the other way around.

Partner-specific obstacles. Developments among Italy's "natural" hydrogen partners may also add to perceived perceptions of peripherality. Key prospective partners in the southern and eastern shores of the Mediterranean are at the moment showing limited interest in hydrogen, and lag behind with RES deployment. In particular, attracting investments has been a challenge for the Algerian energy sector for a long time,[120] while Libya finds itself in a similar predicament due to political instability. The North-African region's commercial and geopolitical challenges may drive North-European demand centres to privilege hydrogen relations with partners more willing to move and more integrated with Europe in regulatory and infrastructural terms. Germany, Belgium and the Netherlands have been showing a will to privilege hydrogen relations with the Iberian peninsula or Ukraine. Four transmission system operators from Germany, Czech Republic, Slovakia and Ukraine are planning a "hydrogen corridor" able to mobilise up to 44 TWhH_2/y by 2030, amounting to 40 per cent of Germany's forecasted demand by that date.[121] In addition, the Southern shore of the Mediterranean is excluded from the Clean Hydrogen Alliance pipeline of projects, while non-EU actors such as Norway and Ukraine are well integrated. The consolidation of such a trend might have unfavourable implications for any Italian ambition to become a regional hydrogen hub.

Uneven intra-EU capacities. Different member states' fiscal capacity to support a demanding infant industry may add to the abovementioned risks of peripherality. While Italy could make the most of funding instruments provided by the EU, national resources will be key. IPCEIs are largely based on member states' resources, so that imbalances may emerge between states with different fiscal capacity. Similarly, EU instruments such as the Just Transition Mechanism could concentrate support for hydrogen clusters in coal regions of Poland, Germany and Romania, while there is limited chance for Italy to access this instrument given an already advanced phase out of coal. EU resources

120 Gonzalo Escribano, "H_2 Med", cit.
121 Edward Martin, "Central and Eastern European Hydrogen Corridor Could Transport over 40 TWh by 2030", in *ICIS News*, 24 September 2021, https://www.icis.com/explore/resources/news/2021/09/24/10688520/central-and-eastern-european-hydrogen-corridor-could-transport-over-40twh-by-2030.

such as NextGenEU may compensate imbalances in the short term. However, according to diverse stakeholders heard during the preparation of the present work, clean hydrogen requires sustained support over time covering both capital expenditure and operational costs, so that fiscal capacity gaps risk marginalising the EU periphery in the future European hydrogen geography. At worst, in case of insufficient support, relocations of future clean hydrogen-intensive industries from the EU's periphery towards the core or towards non-EU low-cost clean hydrogen producers willing to expand down the value chain constitute a risk that should be assessed.

Intra-regional fragmentation. While a certain degree of enthusiasm for hydrogen seems to be shared by EU member states – as demonstrated by a proliferation of national hydrogen strategies – divergent preferences emerged within the EU with respect to technological and infrastructural choices. Germany's strategy privileges green hydrogen, envisaging however a role for blue hydrogen during a transitional phase. France only considers green and pink hydrogen, while Spain intends to support green hydrogen only. The Dutch and Polish strategy adopts a technology-neutral approach. Such a geography of preferences suggests potential frictions over regulatory issues such as guarantees of origin or blending – raising potential issues for cross-border trade, if not properly addressed. Member states also diverge on the external dimension of the hydrogen strategy. The Commission shows a preference for an outward-looking approach that aims at integrating selected neighbours and rely upon external supplies. Such a view is shared by Germany, the Netherlands, Belgium and Spain. In contrast, France's protectionist stance might threaten the connectivity of Spain with the rest of the continent, at worst jeopardising the rationale of Spain's hydrogen ambitions and the buildup of dedicated RES capacity in the Iberian peninsula, also preventing synergies between Spain's solar potential and North-Western European industrial clusters. Protectionist tendencies have emerged as well in Poland, which showed unease for the perspective of the EU importing Russian supplies. To this extent, a tension between the prioritisation of strategic and commercial priorities is emerging along the same terms of a long-standing intra-EU debate on natural gas supplies.[122]

122 Thijs Van de Graaf et al., "The New Oil? The Geopolitics and International Governance of Hydrogen", in *Energy Research & Social Science*, Vol. 70 (December 2020), Article101667, https://doi.org/10.1016/j.erss.2020.101667; Marco Giuli, "Cinquanta sfumature di verde", in *Limes*, No. 12/2020 (December 2020),

Conclusions and recommendations

This brief summary of Italy's asset in an international hydrogen economy provided some clarification on the country's likely positioning. Both the demand and supply potential do not give a straightforward information with respect to the role of the country as a net exporter or importer of clean hydrogen, unlike other European partners such as Spain and Portugal – clearly located among the exporters – and Germany, the Netherlands of Belgium – which are set to become net importers. While the jury is out with respect to Italy's role in hydrogen trade, a clearer picture emerges from other indicators. Italy shows strengths in infrastructure and international connectivity, which may help the country to take the role of a regional transit between low-cost production in North Africa and large demand in North-Western Europe's industrial clusters. Yet, limited storage availability remains a barrier to the pursuit of a regional hub status. In addition, Italy shows important strengths in thermal and mechanical ancillary technologies, that can raise export opportunities towards prospective green hydrogen exporters rich in RES and poor in technology – especially in South America and the Gulf. On the other hand, Italy's weakness in core technologies leaves limited export opportunities in this area, likely to be dominated by German and Asian actors. Material assets can be combined with a number of enabling frameworks at national, European, and multilateral level. In particular with respect to the funding opportunities of the PNRR and Italy's inclusion in a mature, integrated and sophisticated market such as the EU, which has demonstrated a clear will to achieve global leadership in hydrogen technologies. Yet, significant challenges are present. These include Italy's delay in terms of political support and regulation; the lack of a clear, shared perception among Italy's elite and stakeholders about the future of hydrogen; and specific contextual difficulties specific to prospective hydrogen partners of Italy in the neighbourhood. If not tackled, these challenges risk adding to a perception of peripherality with respect to the continent's hydrogen future. To counter these risks, Italy needs to take several actions at both the domestic and EU level aimed at providing political guidance, identifying ways to de-

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risk investments and adopt scalable and uniform options, and establishing as much as possible a common framework with strategic partners. In particular:

Providing political guidance. A proper national hydrogen strategy should propose a clear roadmap with intermediate milestones, where hydrogen development is seen as a part of a systemic vision for industrial transformation. A value-chain centered perspective should be based in particular on the build-up of synergies between the hydrogen valleys and key infrastructural connections – such as ports, and transport and distribution networks – and industrial clusters. At EU level, Italy should promote a coherent approach. Excessive divergences among national strategies and between them and the EU strategy expose the continent to a serious risk of fragmentation, which does not benefit Italy's interests in regional integration. Italy should push for streamlining national roadmaps and make them merge into a regional one. In particular, Italy should work to avoid that different percentages of mandatory or incentivised blending create barriers to cross-border exchanges, and to support a uniform system of guarantees of origins and a harmonised calculation methodology for life-cycle assessment.

Reducing risks. On the supply side, in light of technological uncertainties, it is appropriate to maintain a technological neutrality and avoid dismissing specific routes. However, considering domestic constraints with respect to domestic blue hydrogen production (see section 2), it is safe to assume that any hydrogen strategy is ultimately an electrification strategy. To this extent, Italy should raise its RES objectives for 2030 – currently at 55 per cent, in contrast to 75 per cent of Germany, the Netherlands or Spain – and make sure implementation follows – identifying and tackling administrative barriers that have obstructed the march of RES installations over the last years. On the demand side, to de-risk hydrogen uptake, carbon contracts for difference (CCfD) constitute a proven instrument to facilitate the penetration of emerging technologies in EIIs. With CCfD, a government agrees with an agent a fixed carbon price over a given period in line with the uptake of a given decarbonisation technology. The agent can sell emissions allowances at current carbon prices and be compensated by the difference between carbon prices and the strike price. The mechanism allows for significant transfer payments in the early phase of technological deployment, to become then redundant as soon as the ETS prices become higher. In the transport sector, a favorable taxation or toll regime could apply to hydrogen trucks purchase or use, in line with the approach that was already followed to incentivise LNG for the heavy load transport sector. With respect to the residential and power generation sector, quotas for blending could be considered. However, considering the very limited decarbonisation potential and transitory nature of hydrogen blending, policy options for these sectors should be carefully elaborated while their piloting and possibly temporary nature should be clear. In general, wherever blending results in the delay of inevitable alternatives for full decarbonisation and/or in diverting domestic hydrogen production away from hard-to-abate sectors, it should not be encouraged. Finally, lead markets creation can be performed through performance labelling and public procurement, setting i.e. requirements for basic materials that use hydrogen as an input. At EU level, beside supporting the abovementioned regulatory upgrade, Italy should – in consideration of its limited fiscal capacity – make sure the EU funding for hydrogen projects is sufficiently sustained over time and not simply confined to large one-off recovery interventions such as NextGeneration EU.

Establishing common frameworks. Italy should concentrate its efforts on the most promising partners in the neighbourhood, offering technical assistance and the provision of know-how in the short term, with a view of offering a market outlet in the longer term. Action should follow clear principles helping to start an entirely new trade of hydrogen from scratch. First, cooperation with partners should focus on scalable initiative, that avoids locking partners into technologies that might not be viable in a short time. Actions whose scale up is not foreseen should be deprioritised. A second principle to follow is to make sure to align with partners' interests. To this extent, given the "natural" partners for Italy in North Africa, it is important to work with local ecosystems and specificities. With respect to more external circles, state guarantees in terms of export credit and insurance should be mobilised to consolidate Italian actors' presence and expansion in the most promising future hydrogen producers and exporters – notably in Latin America and the Gulf. At EU level, Italy has an interest to push the EU to mobilise resources (notably through the NDICI) towards North Africans hydrogen schemes, especially targeting Algeria and Tunisia – possibly with a tailor-made approach rather than regional schemes which proved of limited success in the past. The adoption of bilateral action plans, encompassing both RES deployment and hydrogen technologies first for local use, could provide guidelines to coordinate investments in order to pave the way for future hydrogen synergies among the two shores of the Mediterranean. External dialogue should also have a strong infrastructural dimension. To this extent, it should be ensured that, in the framework of the TEN reform, synergies are developed between the energy and transport schemes – especially when it comes to the maritime sector. Finally, Italy should support the establishment of "climate clubs" between the EU and selected foreign partners emphasising bilateral discussion on industrial decarbonisation and trade, in order to make sure to achieve leadership in the process of determination of international standards for hydrogen technologies.

At international level, hydrogen lacks dedicated supportive initiatives, which can bring down costs by favouring sharing information and best practices, and the emergence of an international epistemic community. Such an institution would act as an information repository and develop initiatives to develop a "hydrogen culture", enabling the dissemination of progress in terms of both technology and policy design. It would be possible to arrange such an institution under the premises of the G20, considering the strong interest of many of its members in hydrogen technologies. Finally, Italy should work at promoting and being part of schemes for international research cooperation. While the reality of mounting great power competition is pushing major economies to reduce reliance on international supply chains, international research cooperation remains a key factor to bring costs down. Italy should work to promote university cooperation at international level, leveraging on its own research actors and initiatives. This could be especially done by the EU with emerging hydrogen actors relatively less constrained by the geopolitical imperatives – including Japan, Korea, India, Canada, Chile, Norway, South Africa, and the UK. Cooperation can develop common priorities and establish funding schemes. Research cooperation should focus on areas where breakthroughs have the potential of reducing costs[123] and reducing geopolitical/geoeconomic supply chain concerns.[124]

123 Opportunities for cost reduction especially concern electrolysers and fuel cells. See Matthias Schimmel et al., *Making Hydrogen Cost-Competitive*, cit.; Minhea Catuti et al., "Is Renewable Hydrogen a Silver Bullet for Decarbonisation?", cit.

124 i.e. material efficiency/substitution as for the use of platinum group metals or iridium.

Abbreviations

ACER	Agency for the Cooperation of Energy Regulators
AFID	Alternative Fuel Infrastructure Directive
ATR	Auto-thermal reforming
Bcm	Billion cubic metre
BEVs	Battery electric vehicles
BF-BOF	Blast furnace-basic oxygen furnace
CBAM	Carbon border adjustment mechanism
CCfD	Carbon contracts for difference
CCS	Carbon capture and storage
CCUS	Carbon capture, utilisation and storage
CEF	Connecting Europe Facility
CEM	Clean Energy Ministerial
CF	Cohesion Fund
CO2	carbon dioxide
COP	Conference of the Parties
DRI	Direct reduced iron
DRI-EAF	Direct Reduction Iron-Electric Arc Furnace
EAF	Electric Arc Furnace
EAG	External Action Guarantee
EFSD	European Fund for Sustainable Development
EGP	Enel Green Power
EIIs	Energy-intensive industries
ENNOH	European Network of National Operators for Hydrogen
ENTSOG	European Network of Transmission System Operators for Gas
ENTSOE	European Network of Transmission System Operators for Gas
ERDF	European Regional Development Fund
ETS	Emission Trading System
EU	European Union
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
FCEVs	Fuel-cell electric vehicles
FiD	Final investment decision
FRG	Federal Republic of Germany

g	Gramme
GHG	Greenhouse gases
GW	Gigawatt
GWh	Gigawatt-hour
H2	Hydrogen
H-DRI	Hydrogen direct reduction of iron
IEA	International Energy Agency
INDC	Intended National Decarbonisation Contribution
IPCC	Intergovernmental Panel on Climate Change
IPCEI	Important Projects of Common European Interest
IPHE	International Partnership for Hydrogen and Fuel Cells in the Economy
IRENA	International Renewable Energy Agency
ISO/TC	International Organization for Standardization Technical Committee
ITMO	Internationally Transferred Mitigation Outcomes
Kg	Kilogramme
Km	Kilometre
KWh	kilowatt-hour
LCOE	Levelised cost of energy
LCOH	Levelised cost of hydrogen
LCOS	Levelised cost of storage
LNG	Liquified natural gas
LOHC	Liquid organic hydrogen carrier
MFF	Multiannual Financial Framework
MJ	Megajaule
Mt	Million tonnes
MWh	Megawatt-hour
Mt	Million tonnes
NDICI	Neighbourhood, Development and International Cooperation Instrument
NECP	National Energy and Climate Plan
P2G	Power-to-gas
PNRR	Piano Nazionale di Ripresa e Resilienza
PV	Photovoltaic
R&D	Research and development

REDII	Renewable Energy Directive = II
RES	Renewable energy sources
RFNBO	Renewable fuels of non-biological origin
SMR	Steam Methane Reforming
t	Tonne
TAG	Trans Austria Gas Pipeline
tCO2e	Tonnes of carbon dioxide equivalent
TEN-E	Trans-European Network-Energy
TENP	Trans Europa Naturgas Pipeline
TEN-T	Trans-European Network-Transport
tH2/yr	Tonnes of hydrogen per year
TRL	Technology Readiness Level
TSO	Transmission system operator
TYNDP	Ten year network development plan
TWh	Terawatt-hours
TWh/yr	Terawatt-hours per year
UAE	United Arab Emirates
UK	United Kingdom
US	United States
Wh	Watt-hour

Italy in the International Hydrogen Economy

After many false starts, hydrogen is gaining new traction as a prospective key contributor to deep decarbonisation. As an international trade in hydrogen and hydrogen products is expected in the long term, early movers have chances to strategically position themselves in international hydrogen value chains. This paper explores the potential for Italy to achieve centrality in an international hydrogen economy, identifies enabling frameworks and key challenges, and what policy actions are required to support a competitive positioning. Italy's best assets are a large industrial base, renewable energy potential, infrastructure network and leadership in certain ancillary technologies. Enabling frameworks are emerging especially at the EU levels. Yet, to achieve leadership, it is necessary to develop hydrogen ambitions within the context of a broader plan of industrial transformation and not solely on transmission and connectivity potential.

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