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Report

A Critical Assessment of National Hydrogen Strategies

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Abstract

The scope of this study is to provide a qualitative, high-level overview of the hydrogen strategies currently being pursued worldwide. Hydrogen is a “hot topic” in the envisaged energy transition, and, consequently, a significant amount of material is currently being published. The definition of strategy is not straightforward, as each country adopts specific criteria to set the pace for the deployment of hydrogen. In our review, we selected only official and government-issued documents, for the sake of completeness we include finalized documents and draft versions alike. Specific attention is paid to the so-called “green strategies”, specifically targeting the roll-out of green hydrogen. We assess the documents across a set of qualitative indicators, based on geography, sectorial differentiation, quantitative target sets, information content and word search. The data is not homogeneous and, where possible, we rely on clustering to infer industry trends and patterns and draw conclusions.

We also derive a series of counterfactual considerations from these strategies, in terms of: i) objectives pursued, ii) sectorial coverage and iii) internal consistency.

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01 Hydrogen between ambitions and reality

In envisaging the long-term energy transition, hydrogen is considered, rightly or wrongly, the next “big thing”, regardless of whether its deployment simply complements or constitutes an essential milestone of the decarbonisation process.

The versatility of this energy carrier is well known: the great interest in hydrogen derives from the fact that when it is burned, or used in a fuel cell to generate electricity, the results of these operations are the production of energy, with water vapor as a byproduct (as well as nitrogen oxides in the case of combustion), without any further emissions, especially carbon dioxide or other greenhouse gases. It would therefore seem to be the ideal solution to solve the problems of the transition to a sustainable energy system, but there are at least two main hurdles, intrinsically related to the physical attributes of hydrogen.

The first relevant problem is that hydrogen is an energy carrier (i.e. a means to convey energy) and is extremely rarely found as a primary energy source, therefore it must be produced through chemical, physical or biological processes requiring high amounts of energy. These processes and the production of the electricity needed almost always generate emissions of pollutants and greenhouse gases, thus shifting the problem of environmental impacts from the downstream (the actual use of hydrogen) to the upstream phase (the production of hydrogen). Consequently, the production of hydrogen (namely “grey hydrogen”) is not "neutral" in terms of its carbon footprint.
The second major obstacle is related to the chemical properties of hydrogen, which require great attention and dedicated technologies, so that its transport, storage, distribution and use might take place in safe conditions.
Innovation is likely to alleviate the abovementioned limits, as the Technology Readiness Level (TRL) of different solutions is gradually scaling up aiming at full maturity, as is happening, for instance, with electrolysis or fuel cells. Likewise, new transport and storage facilities, such as the so called “blending” option, are currently being explored, with varied results.

We might add a third issue, which is represented by a fragmented policy framework, paired somehow with a lack of internal consistency, the analysis of which is at the core of this work. The strategic approach to hydrogen shares some common traits across different countries:

- the deployment of hydrogen suffers an absence of “holistic” thinking in terms of the future energy system, that might effectively hamper its technological and economic roll-out. For instance, this is reflected in the insufficient analysis of market fundamentals, with a potential imbalance between future demand and supply, mostly in favour of the latter. We know how much hydrogen we want to produce, while it is less clear which sectors are likely to integrate it in their value chain;

- hydrogen is mostly perceived as a "matter of state" for each specific country: collaboration, even when present, remains at the state level (IPCEI's programme on hydrogen), without the actual participation of markets and economic players. Coordination among the different entities (e.g. producers vs consumers) is therefore marginal. In the past, electricity and gas interconnections, market coupling or the wider ETS market all required close-knit cooperation and a shared regulatory framework;
- targets and objectives are not always clearly set; and consequently, the funds to be allocated are rarely defined. Targets and objectives are not homogeneous across the countries: in some cases, they are quantitatively expressed (e.g. X Mt of green hydrogen produced, or Y thousand fuel cell vehicles deployed), in others they are left purposely vague, where the sole scope is to represent a strategic orientation;
- timing and deadlines for hydrogen deployment are not aligned across countries, with a general vision targeting years 2025 (medium term) and more often 2030 (medium-long term). This implies a perspective to primarily serve the internal market, rather than create a wider one allowing for synergies, export and cross-border trade.

The following excerpts from the strategic document issued by the European Commission ("A Hydrogen Strategy for a Climate-Neutral Europe", 2018) summarize the pan-European strategy. It is relevant to note how this document is not compulsory in nature, as much space is left to the draft and definition of national energy strategies:

> *In the first phase, from 2020 up to 2024, the strategic objective is to install at least 6 GW of renewable hydrogen electrolysers in the EU and the production of up to 1 million tonnes of renewable hydrogen, to decarbonise existing hydrogen production, e.g. in the chemical sector, and facilitating take up of hydrogen consumption in new end-use applications such as other industrial processes and possibly in heavy-duty transport.*
>
> *In a second phase, from 2025 to 2030, hydrogen needs to become an intrinsic part of an integrated energy system with a strategic objective to install at least 40 GW of renewable hydrogen electrolysers by 2030 and the production of up to 10 million tonnes of renewable hydrogen in the EU29.*
>
> *In a third phase, from 2030 onwards and towards 2050, renewable hydrogen technologies should reach maturity and be deployed at large scale to reach all hard-to-decarbonise sectors where other alternatives might not be feasible or have higher costs. In this phase, renewable electricity production needs to massively increase as about a quarter of renewable electricity might be used for renewable hydrogen production by 2050.*

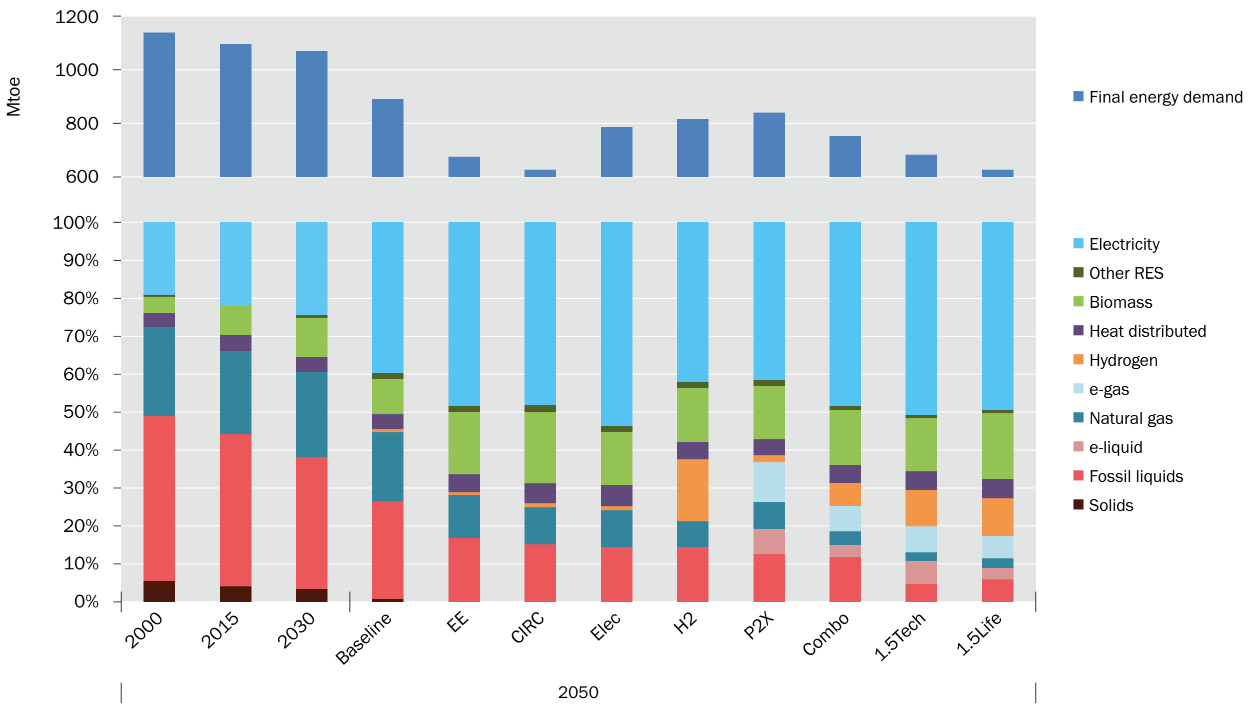
Again, the quantitative focus is set in terms of production, while the demand side is somehow sidestepped.

Another important element, pending the pursuit of the energy transition and the reduction of greenhouse gas emissions, is represented by the fierce competition of concurrent scenarios: it is clear that pursuing an inconsistent strategy can prove to be, in the long run, not only an expensive choice, but also an ineffective one in terms of the rational use of resources and the creation of new jobs and services.
As an example, the European Commission document "A Clean Planet for All" (2018), provides, among other things, the following five scenarios, modelled up to 2050:

- ELEC scenario, based on the transition from direct use of fossil fuels to electricity;
- H2 scenario, based on a switch to hydrogen;
- P2X scenario, based on a shift to e-fuels;
- EE scenario, based on a strengthening of energy efficiency measures;
- CIRC scenario, based on the adoption of the circular economy.

Figure 1 below depicts the composition of the overall energy demand in the EU, according to the different scenarios.

Figure 1: Composition of Energy Demand



Source: European Commission (2018)

In this perspective, a hydrogen scenario is one of the options on the table, and not necessarily the most efficient one. In particular, an electrification scenario currently presents a number of advantages over a hydrogen one: for instance, a more favourable energy conversion, an achieved technological maturity of electric pumps vs hydrogen-fuelled heaters, or the relevant introduction of electric vehicles and associated infrastructure vs mature but still niche fuel cell solutions.

Planning an energy transition (also) based on hydrogen is certainly possible and potentially highly beneficial, but requires detailed consideration of the alternatives, and a comprehensive (or its more appreciated equivalent, holistic) planning of costs and benefits, supply and demand.
Do current hydrogen strategies address all the above? With this work, we aim to provide a preliminary answer.

02 Assessing strategies: objectives of the study

This work focuses on the qualitative analysis of the hydrogen strategies at world level. As anticipated in the previous section, this task is not straightforward: i) there is no clear definition of what a "strategy" is, apart from the document's name, officially bestowed by a government or ministerial entity, ii) the focus and/or commitment to the deployment of hydrogen ranges from complete naivety to well detailed and tangible plans and iii) the topic per se, being a "hot" one, is subject to radical changes, as new strategies are being published and old ones are being updated or refined.

Generally speaking, a "national hydrogen stretegy" is an official document, issued by a governmental or public entity (e.g. government, competent ministry), setting broad strategy objectives and aiming at one or more of the following:

- Proposing targets, both in terms of hydrogen deployment and/or reduction in emissions enabled by the introduction of hydrogen;
- Setting timelines and/or defining implementation phases;
- Highlighting the main sectors of interests from the demand side (e.g. transport, residential or hard-to-abate sectors) and the supporting measures to promote a widespread adoption;
- Addressing the preferred production technologies from the supply side, by stressing existing technology gaps and the needed framework or support for the development of those solutions;
- Providing a general orientation in terms of approach to the market, such as: green vs blue hydrogen (or a mix of the two), export-oriented production vs internal market, transport, storage, blending and sector coupling;
- Anticipating the allocation of funds, or investment facilities, to steer interest from the public and private sectors alike; prioritize interventions and reiterate government commitment.

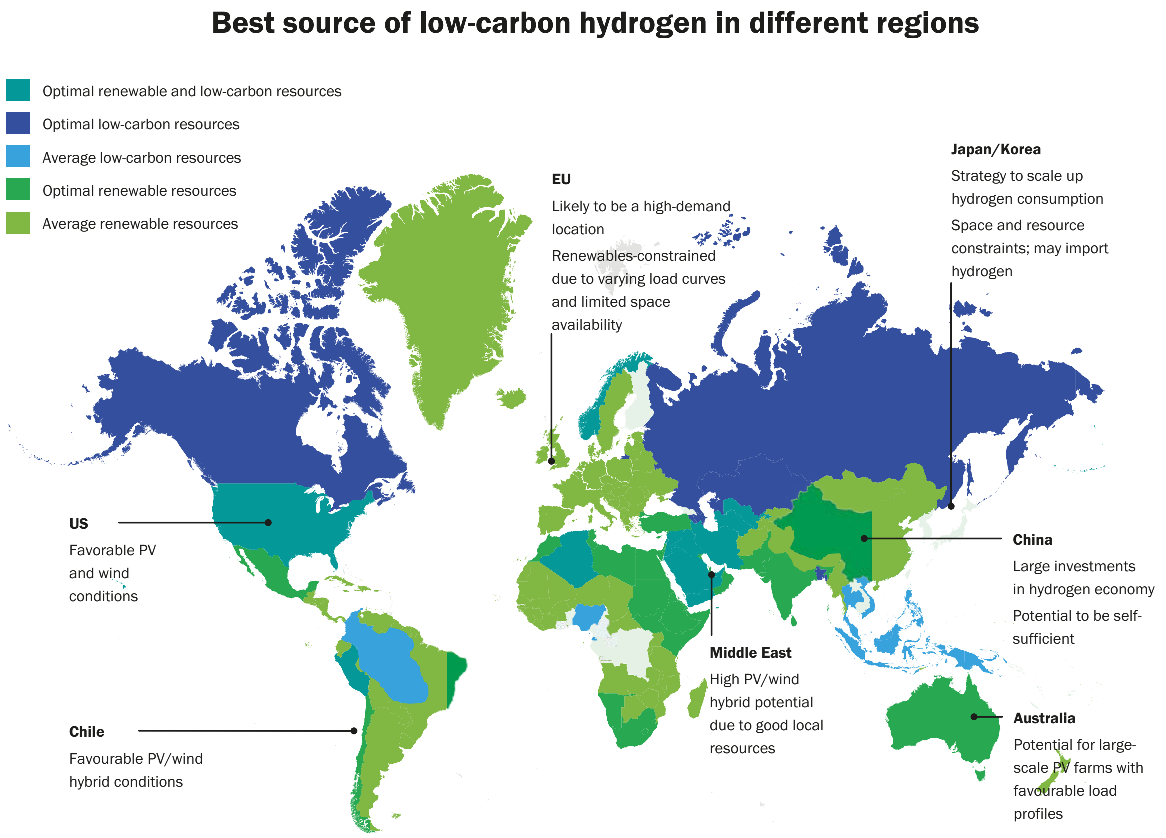
To the best of our knowledge, few other studies have cross-compared the international hydrogen strategies with a similar methodological approach. One example is the report from the World Energy Council (2020), wihch provides an insightful analysis on 16 government actions on hydrogen (United Kingdom, Japan, South Korea, Australia, the Netherlands, France, Italy, Spain, China, Ukraine, Germany, Switzerland, Morocco, California, Russia, Norway and the European Union), selected out of 56 countries at world level. The final dataset is similar to that assessed in this study, with a focus on national goals, targeted sectors and infrastructures, current support measures, requirements on the hydrogen used, and achievements. However, as highlighted in the next section, the methodology used in this study, the primary scope, as well as the definition of hydrogen strategy, are slightly different.

The World Energy Council study also provides a clustering by the strategic goals set by the government actions, highlighting, for each goal, the intrinsic relevance (main goal, less relevant or not addressed). As straightforward as they might seems, some of these goals are not always quantitatively specified, or even mentioned, in the official documents:

- Reduce emissions (main goal in 12 countries, less relevant in 5 countries);
- Diversify energy supply (main goal in 6 countries, less relevant in 7 countries);
- Foster economic growth (main goal in 11 countries, less relevant in 5 countries);
- Support national technology development (main goal in 13 countries, less relevant in 3 countries);
- Integrate renewables (main goal in 12 countries, less relevant in 5 countries);
- Develop hydrogen for export (main goal in 5 countries).

The geographical dimension is also explored in a report by Hydrogen Council and McKinsey (2020) with reference to production, namely the choice between pursuing blue hydrogen (natural gas reforming + CCS) or green hydrogen (electrolysis + renewables). Export options are similarly explored, see Figure 2 below.

Figure 2: Hydrogen Production Potential across Regions



Source: Hydrogen Council and McKinsey (2020)

Quite Interestingly, in a more recent report, Hydrogen Council and McKinsey (2021) complement a similar map with approximate circles pointing out the areas representing "demand centres".
In the same reports, potential applications (the demand side) are, on the contrary, broken-down by sector: again, a potential limit and a misalignment: the underlying narrative seems to imply that the planning of hydrogen production pertains to state entities, while demand should be generally left to market forces, tackling more or less effectively the relevant issue of the integration and absorption in their supply chains of future massive quantities of hydrogen. As we will see, this approach is consistently reflected in the strategies, where supply side policies outnumber demand side policies.

The scope of this work is to shed some critical (and therefore positive) light on similar inconsistencies by relying on a comparative approach. The general approach is to:

- Collect national strategies and related documents (e.g. draft versions, green papers, discussion papers, etc.);
- Cluster data at macro category level;
- Provide qualitative and quantitative insights;
- Derive cross-country macro trends;
- Focus on the policies governments are willing to implement;
- Focus on the sectors of use of hydrogen.

We assess hydrogen strategies over a set of qualitative indicators, based on geography, sectorial differentiation, quantitative targets set, information content and word search. Where possible, we provide segmentation at policy level.
Data is not homogeneous and, where possible, we rely on clustering to infer industry trends and patterns and draw conclusions.
We derive a series of counterfactual considerations on these strategies, in terms of: i) objectives pursued, ii) sectorial coverage and iii) internal consistency.

03 Methodology

The collection and selection of the documents to be included in the dataset followed a rigorous approach: the final documents had to either be “hydrogen strategies” (i.e. official documents issued by governmental bodies and labelled as such) or “draft strategies” (sometimes labelled also as “green papers”, “discussion papers”, “visions”) (i.e. official preparatory/discussion documents that pave the way to the formalization of the country’s hydrogen strategy):

- Build-up of a solid base of "guidance" documentation to provide an in-depth knowledge of the current hydrogen market situation (all kinds of hydrogen-focused documents excluding academic papers). Many of these documents were only used for reference, and provided for a solid literature on previous work;
- Collection of specific documentation (e.g. hydrogen strategies and draft strategies) through the use of Factiva and the Governmental websites of countries around the world;
- Through the use of reference management software (Mendeley), the bulk of documents has been collected and catalogued via a tag-based classification system. Mendeley automatically provides the following default tags: Title (original language), Author Name, Publication Year, Number of Pages, URL, Notes. A further tag system was then specifically designed to fit the documents characteristics and to address the purpose of the study;
- Tag system: general tags for all the documents,
  - Author Identification: Governmental Institution, Consulting Company, Think-tank, Public Private Partnership (PPP), etc.
  - Typology of document: National Strategy, Draft Strategy, Roadmap, International Agreement, Supportive and Preparatory Studies (SPS), etc.
  - World region: AF (Africa), AS (Asia), EU (Europe), NA (North America), OC (Oceania), SA (South and Central America), World
  - Level of analysis: National, International, Regional
  - Focus of the document: World focus (WF), Energy, Policy, Financing, Market, Industry
  - Officialdom of the document: Official, Non-official, Unclear Origin (UO)
  - Specificity on hydrogen: Specific, Non-specific;
- Two categories of tags specific to national hydrogen strategies:
  - Time span considered: To 2025, To 2030, To 2040, To 2050
  - Kick-off date (of the strategy): From 2018, From 2019, From 2020, From 2021, etc.

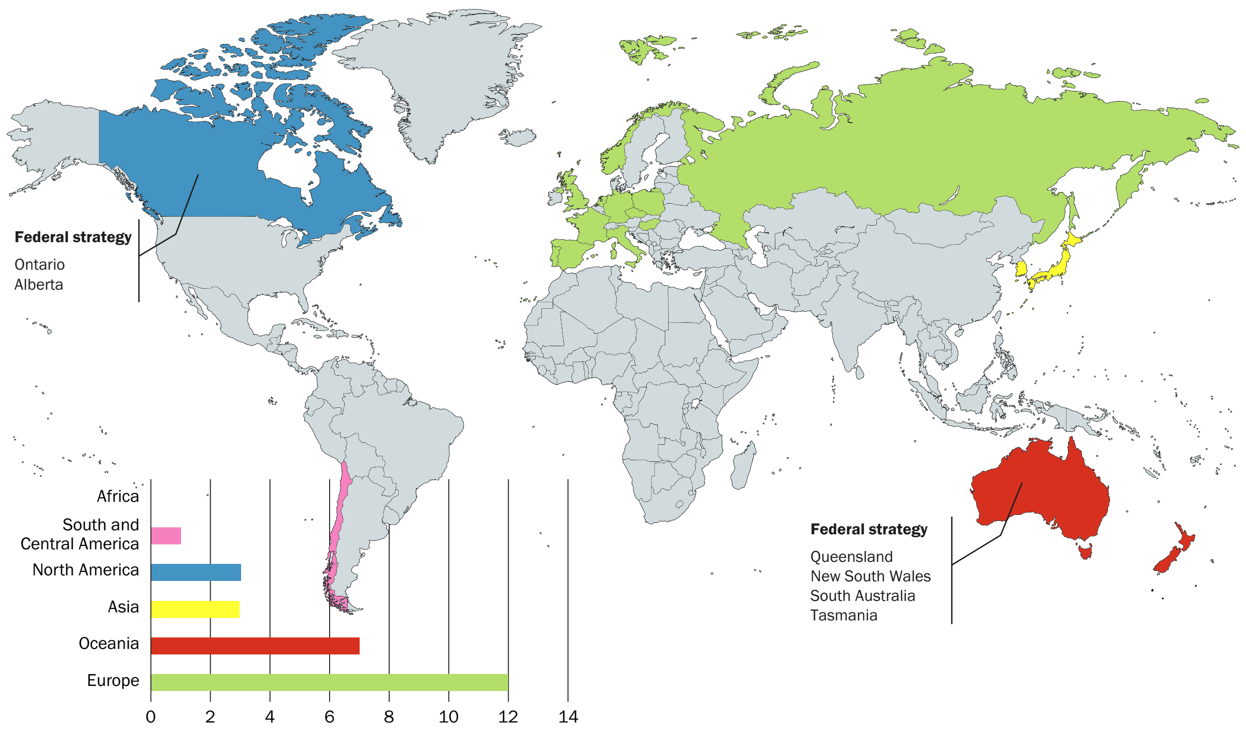
04 Data

The resulting dataset comprises 26 observations, corresponding to strategies and draft strategies (a class containing also green papers, discussion papers, visions and all the non-definitive documents in preparation of a national strategy). All observations are from governmental sources (tags Officialdom of the document: Official and Author Identification: Governmental Institution).

Figure 3 below shows whose countries, at the current date, published strategies or akin documents. Our final dataset comprises strategies of:

- Australia;
- Australia - New South Wales;
- Australia - Queensland;
- Australia - South Australia;
- Australia - Tasmania;
- Australia - Western Australia;
- Canada;
- Canada - Alberta;
- Canada - Ontario;
- Chile;
- Czech Republic;
- Europe;
- France;
- Germany;
- Hungary;
- Italy;
- Japan;
- Korea;
- Netherlands;
- New Zealand;
- Norway;
- Poland;
- Portugal;
- Russia ;
- Spain;
- United Kingdom.

Figure 3: Composition of the dataset



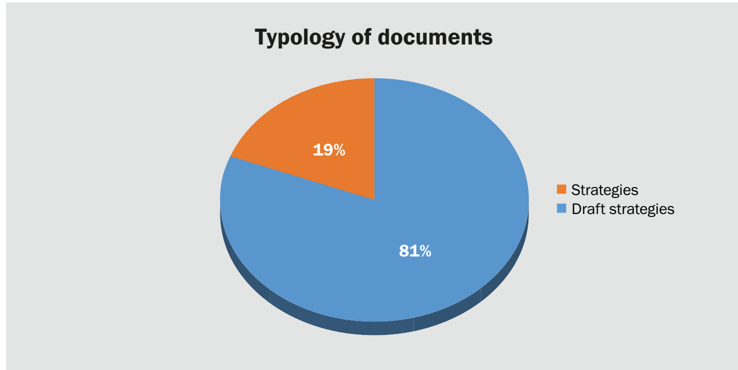
Source: FEEM Elaboration

The dataset comprises strategies from single states within federal countries, such as Ontario and Alberta in Canada, Queensland, New South Wales, South Australia and Tasmania in Australia.

Interestingly, according to our criteria, neither China nor the United States (or single states within the US) have yet formalized hydrogen strategies (other reports provide different findings, and used a less rigorous approach to define officialdom).

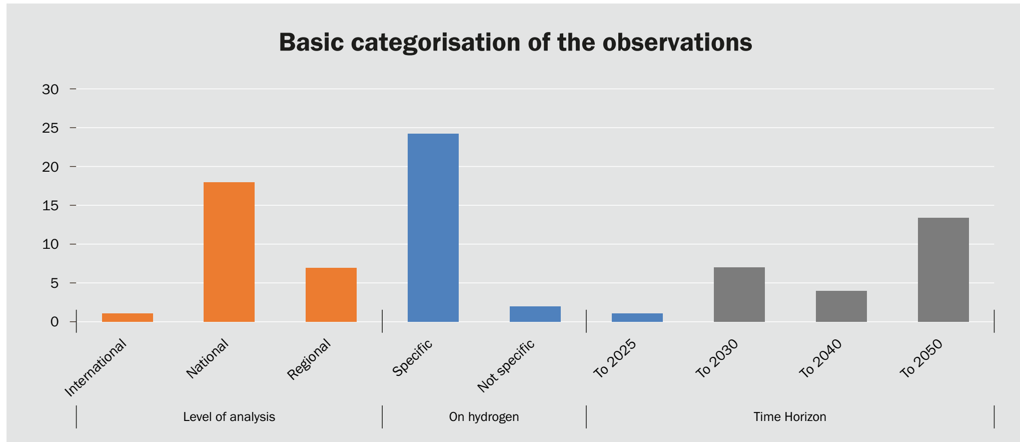
Figures 4 and 5 provide a preliminary break-down of the documents collected in the final dataset. There is a gradual shift towards the definition of strategies, as draft strategies are gradually converted into finalised documents. Time Horizon is generally focused on the medium and long term (2030 and 2050, respectively), thus allowing for a general ambiguity and lack of definition of the documents (e.g. in terms of quantitative targets and allocated funds).

Figure 4: Typology of documents



Source: FEEM Elaboration

Figure 5: Categorisation of observation



Source: FEEM Elaboration

Further data specifications have been provided based on the following:

1. Categories identified by tags were arranged via a set of dummy variables (1 for each category that applies, 0 if a category does not apply), aimed at allowing for quantitative handling of data.
2. Additional variables were introduced, providing further specifications on the observations, with a focus on the policies in support of hydrogen, see Annexes for a list of the variables included:
   - **Categorical variables**, aimed at classifying the strategy content by different criteria: *e.g. type of policy adopted, target years, focus of the strategy*, etc.
     There is a focus on the type of policies adopted, broadly divided into General (see below), Financial (allocation / destination of funds is present) and Target (a quantitative specification is present). These are likewise arranged via a set of dummy variables (1 for each variable that applies, 0 if a variable does not apply);
   - **Quantitative variables**, aimed at collecting numerical information of the strategies: *e.g. number of policies, quantitative targets, amount of demand*

or supply of hydrogen, etc. We opted to report and store these data, regardless of their actual use for the scope of this work, to enhance further analysis.
As previously mentioned, the quantitative data available in strategy documents is not homogeneous.

3. Economic and energy indicators associated with each specific country whose strategy document is present in the final dataset.

Data are taken from the Enerdata and IEA databases. These figures make it possible to better categorise the countries which are implementing hydrogen strategies, their affinities and differences at the macroeconomic and sectorial level, and derive some further insights on the way the industry is moving forward. Descriptive statistics of the abovementioned indicators are reported in the Appendix.

05 Key findings

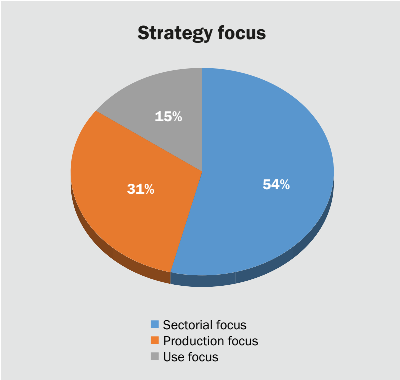
The qualitative analysis presented in this study yielded a set of descriptive considerations, which are broadly classified as follows:

1. Macroeconomics and energy sector;
2. General Policy: Sectorial, Production and Export;
3. General Policies: Uses of Hydrogen.

The uses of hydrogen have been assessed in more detail, as the strategy documents provide much granularity on future potential applications.

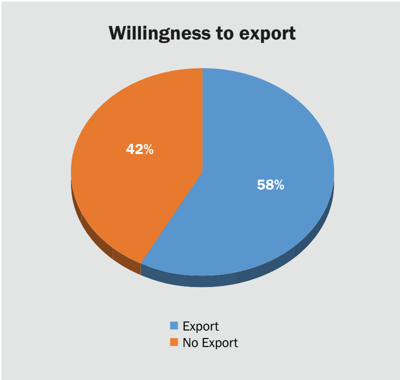
Figures 6, 7 and 8 below provide some preliminary insights

Figure 6: Strategy Focus



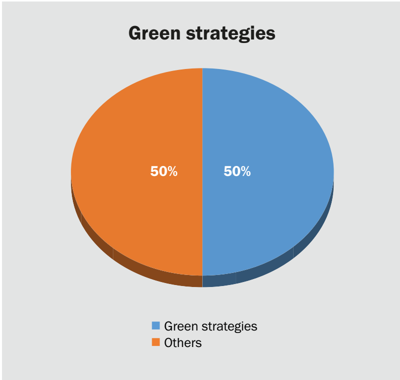
Source: FEEM Elaboration

Figure 7: Willingness to export



Source: FEEM Elaboration

Figure 8: Green strategies



Source: FEEM Elaboration

There is a clear tendency (54%) to align strategies on the whole value chain in terms of measures adopted. The most common objective is to support the upstream and downstream phases simultaneously, and therefore a sectorial focus is preferred.

58% of the strategies are plan to export hydrogen. Such statements are strongly at odds with the strategic focus identified by the pioneer countries, less centred on measures to enhance production.

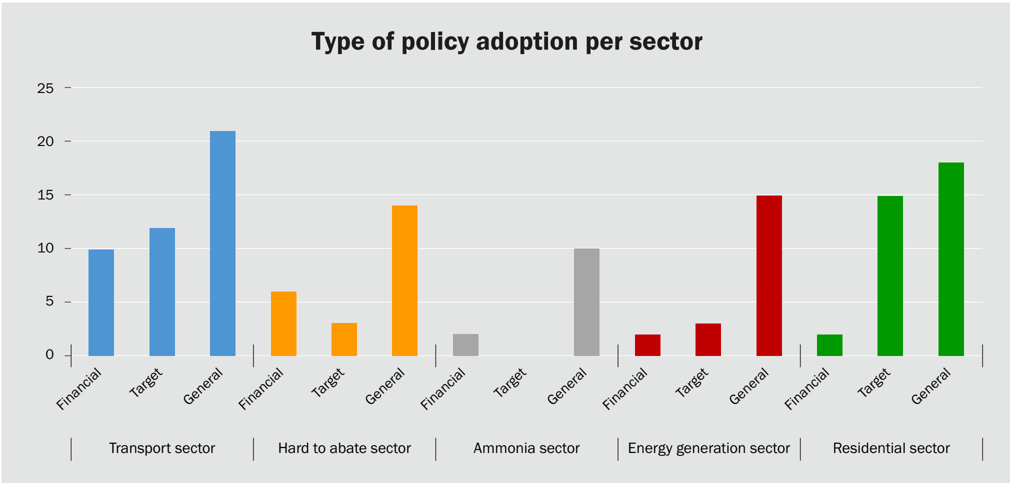
Half of the strategies are “green strategies”, targeting the deployment of green hydrogen from electrolysis. This is particularly true for hydrogen producers with abundant renewable electricity generation, such as Canada or Australia (2 and 4 state-level strategies, respectively)

Figure 9 below shows the conceptual framework used for the analysis of polices presented in the hydrogen strategies. The chart depicts the number of countries where at least one type of policy is present. Policies are structured according to the following framework:

1. Category of the policy, divided into:
   - Production, pertaining to production of hydrogen;
   - Export, pertaining to the export of hydrogen;
   - Use, pertaining to the different final uses
   - Sectorial, pertaining to the whole sector/ value chain of hydrogen, without a specific focus;
2. Type, divided into:
   - Financial (dummy variable), pertaining to the perspective allocation of funds;
   - Targets (dummy variable), pertaining to the definition of quantitative targets (e.g. FC vehicles, Mt hydrogen produced);
   - General (categorical variable), description of the impacted area of the hydrogen value chain, examples of General Policies are listed below:
     - R&D;
     - Demand side policies (see Appendix for details);
     - Supply side policies (see Appendix for details);
     - International cooperation (e.g. regulation, alignment of producing and consuming countries);
     - Education and skills development;
     - Standards (e.g. technical aspects related to hydrogen deployment);
     - Guarantees of Origin system;
     - Hydrogen hubs;
     - Infrastructure development;
     - Internal regulatory framework (e.g. removal of barriers and internal regulation for hydrogen implementation, production and use).

In this graph general policies are considered as dummy variables, therefore the existence of one or more of the policies listed above is in any case counted as one (presence of general policies).

Figure 9: Type of Policy per Macro-group (26 countries)



Source: FEEM Elaboration

General policies are predominant across all sectors, implying that the definition of quantitative targets or financial funds is difficult at this stage. Current strategies point to an approximate direction to the deployment of hydrogen, but are not aimed at providing specific commitment.

Likewise, the high presence of financial policies at sectorial level, rather than a specific allocation in a segment of the value chain, could indicate lack of specificity in the support process, as well as an inefficient allocation of budgets.

Countries with policies specifically targeting export are minimal, which is in conflict with the prospective focus on exporting (green) hydrogen. This seems to support a preliminary conclusion that the export option represents a general will, whose clear definition has been postponed.

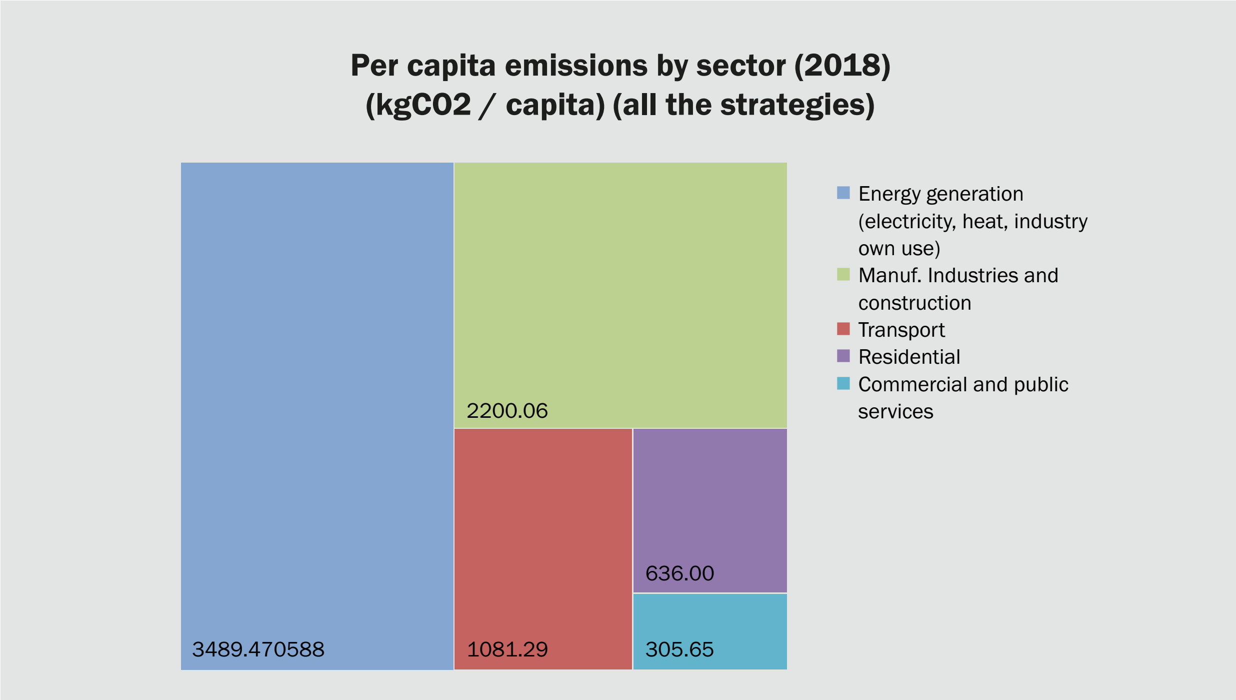
5.1 Macroeconomics and energy sector

The introduction of economic and energy indicators allows for the identification of some common patterns across the countries pioneering hydrogen worldwide.

Figure 10 below provides the emissions in the selected countries, expressed in kgCO2/ per capita, suggesting the two dimensions that are pivotal to for the successful roll-out of hydrogen solutions:

- The energy generation sector (including electricity, heat and industry own use), presents ample margins on improvement and emissions abatement, especially in the many countries relying on important shares of thermal generation (coal, natural gas). These countries are naturally considering hydrogen, namely green hydrogen from renewables + electrolysis, as a clean solution to modernise their generation mix. Likewise, in the heat supply chain, blue hydrogen and CCS can play a pivotal role, in terms of sector coupling and efficiencies, especially where an extensive natural gas infrastructure is already in place;
- The transport sector (including public transport) is the other main culprit of emissions. Consequently, many strategies focus on the deployment of fuel cell technology for a variety of vehicles, such as buses, trains, industrial vehicles and private cars;
- The manufacturing and construction sectors comprise much of the hard-to-abate segment, where hydrogen solutions are currently being studied, such as refining and steel production.

Figure 10: Emissions per Capita by Sector (2018)

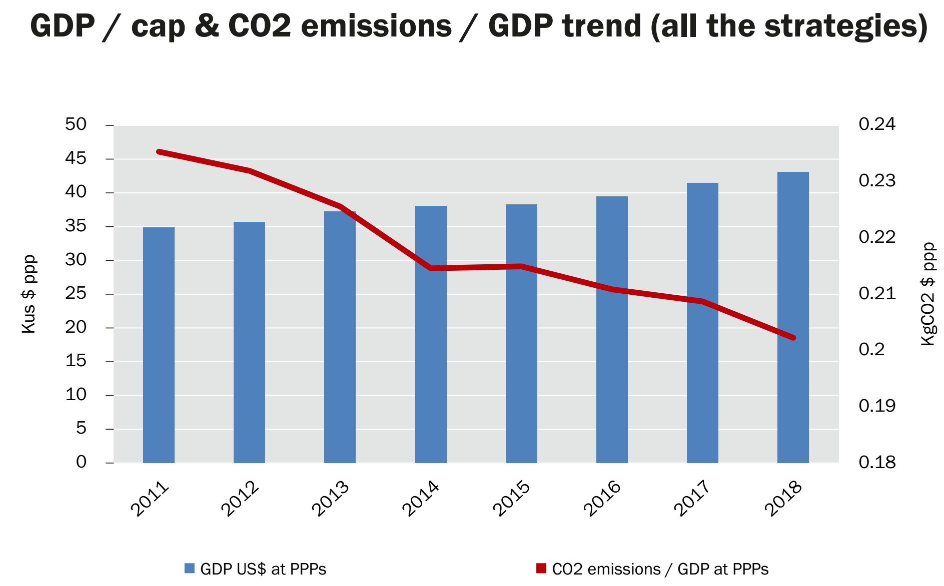


Source: FEEM Elaboration on Enerdata

Figure 11 below depicts the historical trend of GDP per capita vs CO2 emissions per GDP unit (kg per USD in PPP). Unsurprisingly, the pioneering countries are also the most technologically advanced, currently expediting the decoupling of GDP generation and CO2 emissions, as illustrated for instance by Lanza and Galeotti (2021). The decoupling of economic growth and emission abatement is pertinent to developed countries, where containment measures are in place and enforced, and does not generally apply to many emerging markets.

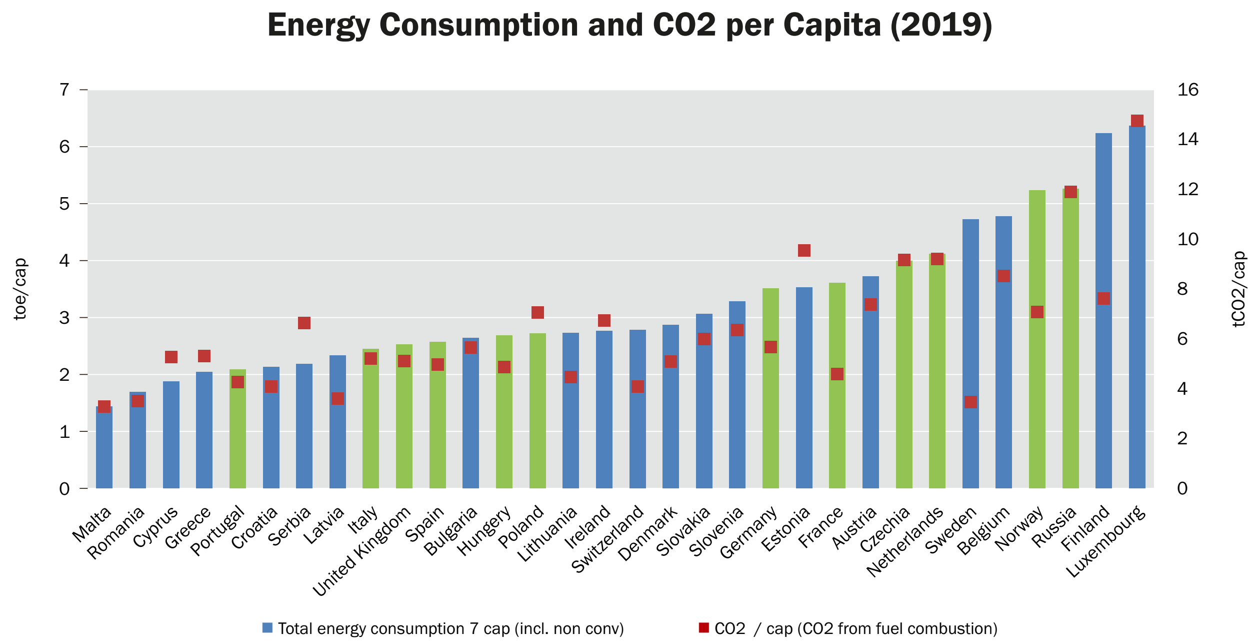
Figure 12 provides a consistent indicator, by plotting the energy consumption (in tonnes of oil equivalent per capita) vs CO2 emissions per capita (in tonnes), per each European country, where the green bars represent countries that already introduced hydrogen strategies (i.e. included in our dataset). This data do not provide a straightforward interpretation: while some pioneering countries present interesting similarities (UK; Italy and Spain; Germany and France), it appears that the two quantities and the decision to roll-out hydrogen strategies are currently disentangled, as for instance can be seen in the most energy-intensive countries. In absolute terms, the most relevant consumption is concentrated in the big countries (Russia, Germany, France, UK, Italy, Spain), all currently pursuing hydrogen strategies.

Figure 11: GDP per Capita vs. CO2 Emissions per GDP unit (2011-2018)



Source: FEEM Elaboration on Enerdata

Figure 12: Energy Consumption and CO2 per Capita (2019)

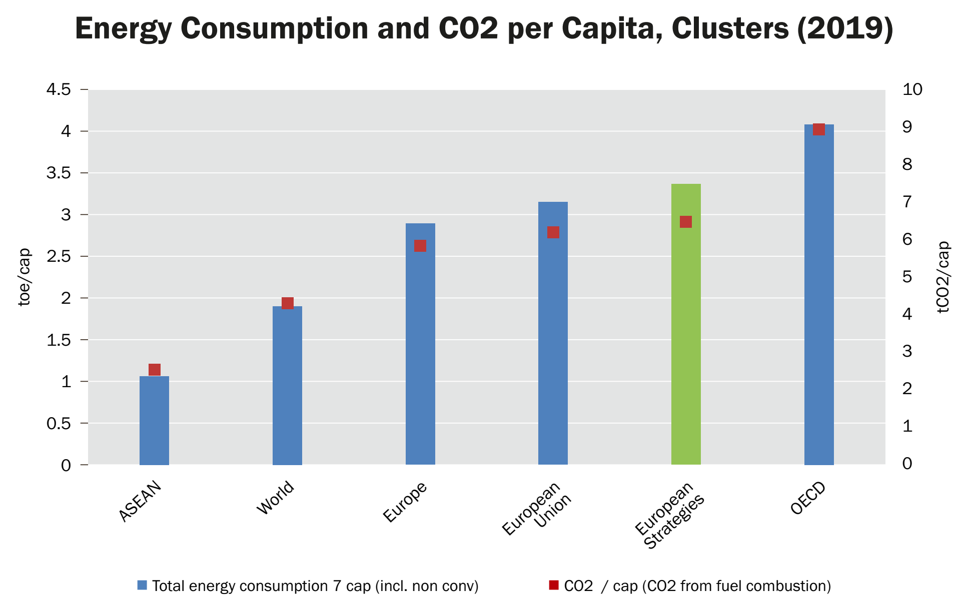


Source: FEEM Elaboration on Enerdata

Finally, Figures 13 and 14 below plot energy consumption (in tonnes of oil equivalent per capita) and electricity consumption (in kWh per capita) vs CO2 per capita (in tonnes), by also clustering per regional organizations (ASEAN, World, Europe (continent), the European Union, European countries proposing strategies, the OECD).

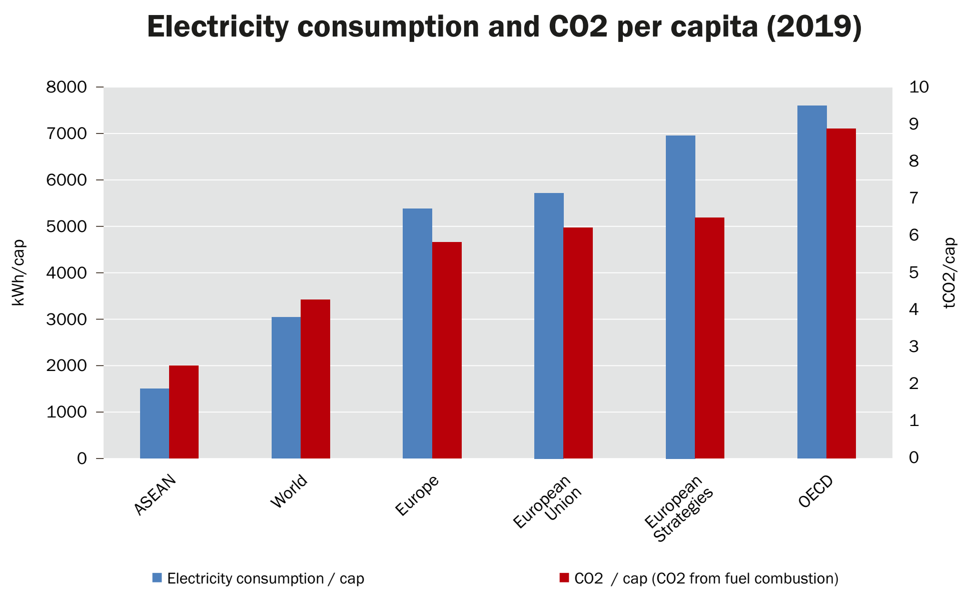
Again, countries proposing hydrogen strategies make it to the upper end of economic development, with a higher than average energy intensity.

Figure 13: Energy Consumption and CO2 per Capita, Clusters (2019)



Source: FEEM Elaboration on Enerdata

Figure 14: Electricity Consumption and CO2 per Capita, Clusters (2019)



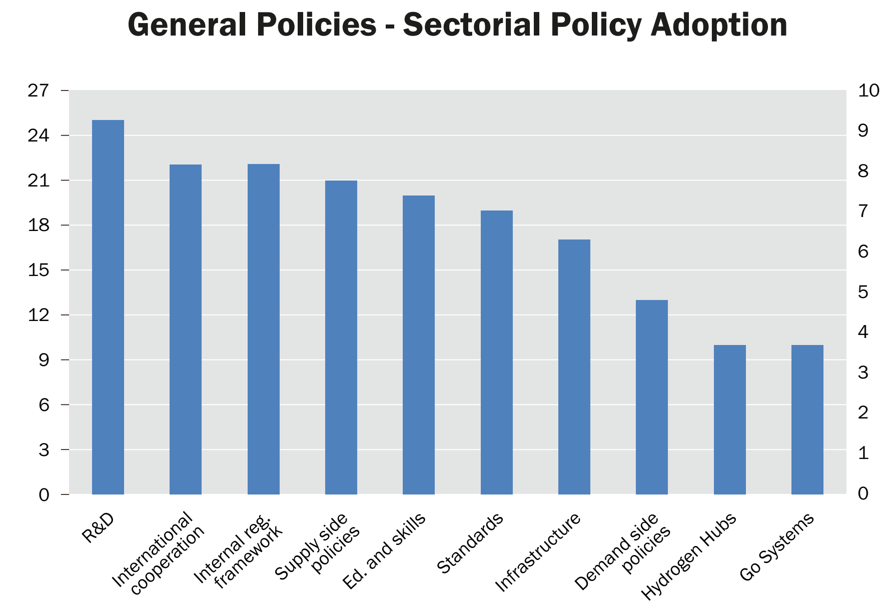
Source: FEEM Elaboration on Enerdata

5.2 General Policies

General policies constitute the core of this analysis and have been assessed in detail. In the following sections the number of countries presenting a least one general policy, according to the four identified macro-categories (Sectorial, Production, Export, Use), is illustrated. For the sake of clarity, it is important to remember that the terms Sectorial policies, Production policies, Export policies and Use policies refer to the General policies of the above mentioned identified categories.

5.2.1 Sectorial Policies

Figure 15: General Policies - Sectorial Policy Adoption



Source: FEEM Elaboration

Sectorial policies are the largest category found in our dataset: these are related to the whole value chain of hydrogen and are widely used in the strategies to assert the commitment towards hydrogen. Many of these measures are generic and not corroborated by numerical evidence or specifications.

R&D and Education and Skills Development remain key measures. The majority of the strategies reflects the willingness to further increase still limited knowledge in both the fields of production and uses. At the same time, Collaboration at International Level plays a vital role. The will to cooperate among national entities passes through the desire to share know-how and, in second place, through attention to international market requirements and needs. Although the latter, as already mentioned, is far from being a reality, examples of international market cooperation can be described as straightforward with the idea that: in the sense that Exporters want to secure market outlets and importers want a steady supply of hydrogen. Since the level of uncertainty brings quite high market risks (especially volume risk), strategies advocate, albeit in generic terms, International Collaboration.

The hydrogen logistics sector is reflected in Infrastructure development and, marginally, in International Cooperation, and relates to:

- Transnational pipelines;
- Shipping routes.

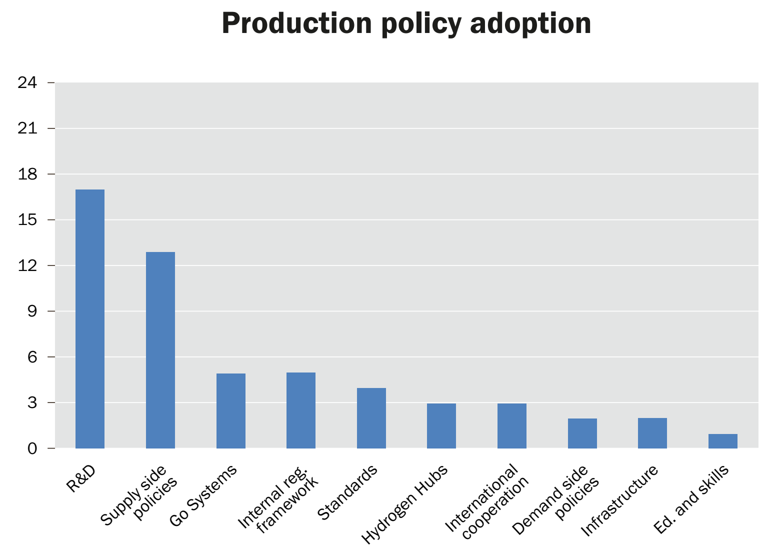
However, no specific mention or particularly deep analysis of the logistic side of the market has been found in the strategies.

The establishment of systems of Guarantees of Origin is a measure proposed by almost all would-be hydrogen exporters that wish, once again, to secure a competitive advantage for their green hydrogen on the market. Sometimes this discussion on Guarantees of Origin concerned the level of purity of the hydrogen produced.

A fundamental role, in addition to those already mentioned, is played by the "Internal Regulatory Framework" policy: 22 countries out of 26 identify numerous legal barriers (maritime fuel bans, blending solution limitations, injection in the gas grid regulation, identification as a chemical product and not as an energy carrier with all the restrictions linked to this category, etc…) to the implementation of a hydrogen economy. This triggered a shared surge in the process of identification and elimination of constraints to the broad use of hydrogen and the development of a hydrogen economy.

5.2.2 Production Policies

Figure 16: General Policies - Production Policy Adoption



Source: FEEM Elaboration

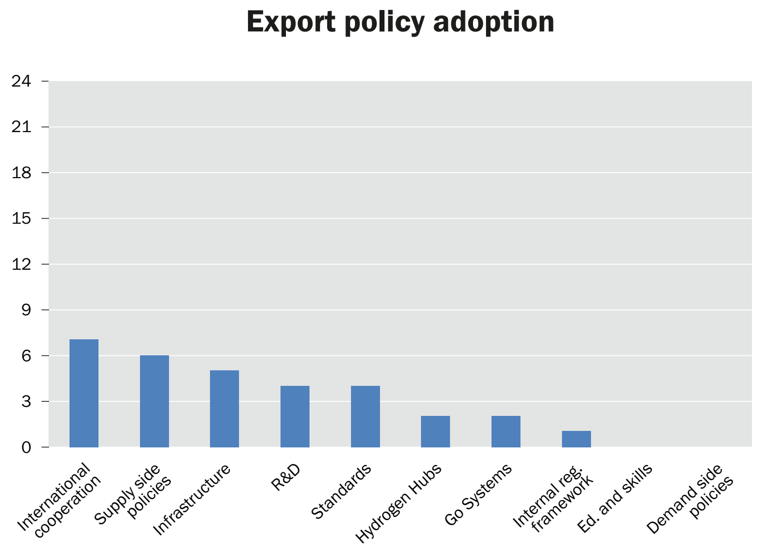
Production policies focus on all activities related to the production of hydrogen, namely green and blue hydrogen.

R&D is predominant, reflecting the focus on the development and deployment of new production technology, with a specific attention on electrolysers for green hydrogen, currently at a low TRL.
Consequently, Supply Side policies reveal the need to subsidize green and blue hydrogen production, still far from cost competitiveness.

The relatively low interest in actively supporting (also financially) green hydrogen production is emblematic of how many of the strategies focus on the end uses of hydrogen rather than addressing the up-stream sector. A fair number of pioneer countries aims at decarbonising through hydrogen without actually addressing the production side.

5.2.3 Export Policies

Figure 17: General Policies - Export Policy Adoption



Source: FEEM Elaboration

Export policies focus on the envisaged export of hydrogen, mainly promoted by countries with a rich endowment of renewables.
The comparative relevance of International Collaboration highlights the need to secure an outlet market for would-be exporters: there are still great uncertainties in terms of hydrogen trade possibilities, and the issues related to logistics are generally not tackled in the strategies. A fundamental role will be played by infrastructure development (mainly transnational pipelines, also requiring international cooperation, shipping vessels and hydrogen hubs often located in ports).

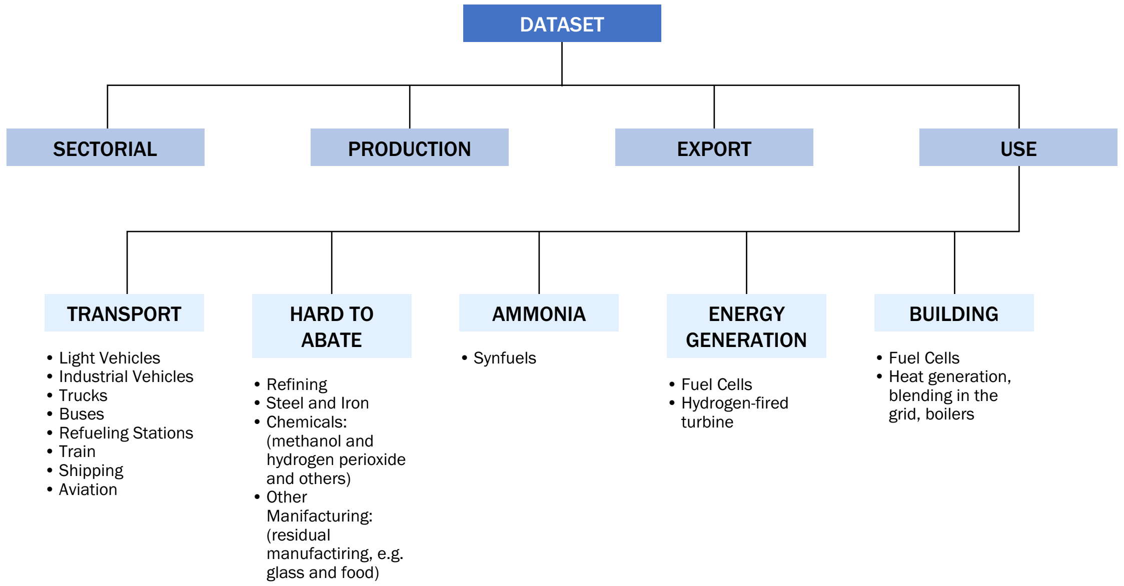
The almost total absence of export support policies is strongly at odds with the willingness of more than half of the countries studied to export hydrogen. However, it is interesting to note that most export support policies are polarised within three large aspiring exporters (Canada, Australia and Chile). It seems that the rest of the countries willing to export hydrogen have in no way considered measures to support the aims (this lack of support can also be explained by the desire to create in the short term a stable economy and internal value chain and only in the long term to address export opportunities).
From this close analysis of both production and export prospects, a clear trend emerges.
It seems an increasingly centralized market topology is developing in which large hydrogen exporters seek to provide supply to the rest of the world.

5.2.4 Uses Policies

The potential uses of hydrogen are much more clearly specified and broken down in strategy documents, compared to other categories. This is only partially counterintuitive, as the demand side is generally less covered, but, in reality, much supply side targeting focuses on enabling the gradual opening of a market for hydrogen solutions.
We broadly divided the uses into the following sub-categories, each is further broken-down into further sub-categories, see Figure 18:

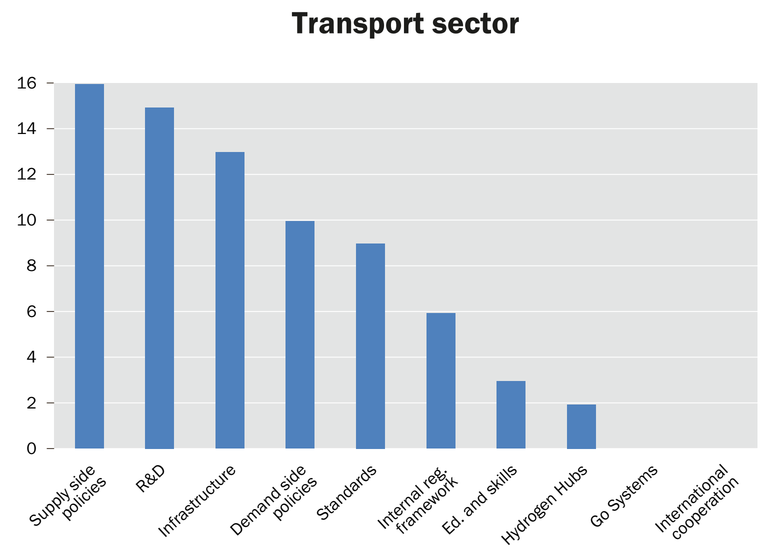
- Transport (Light Vehicles, Industrial Vehicles, Trucks, Buses, Refuelling Stations, Trains, Shipping, Aviation);
- Hard-to-Abate (Refining, Steel and Iron, Chemicals: methanol and hydrogen peroxide and others, Other Manufacturing: residual manufacturing, e.g. glass and food);
- Ammonia (Synfuels);
- Energy Generation (Fuel Cells, Hydrogen-powered turbines);
- Residential (Fuel Cells, Heat generation, Blending in the grid, Boilers).

Figure 18: Hydrogen Uses: Categories and Sub-categories



Source: FEEM Elaboration

Figure 19: General Policies - Use Policy Adoption (Transport)

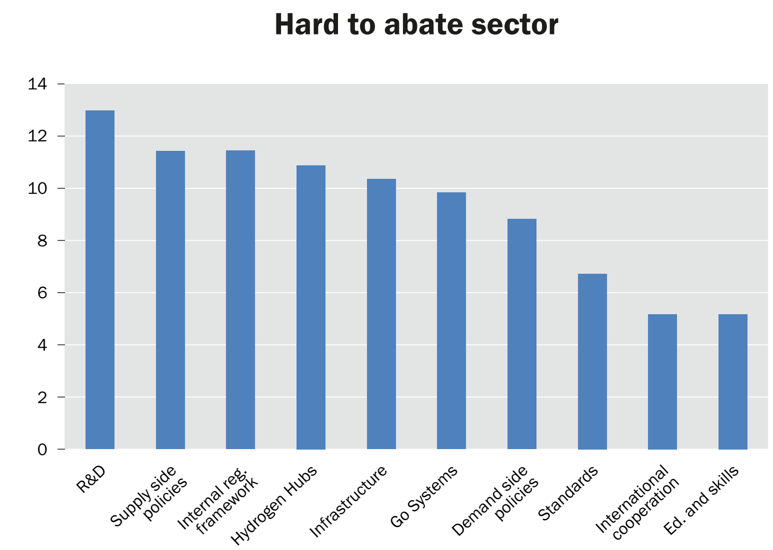


Source: FEEM Elaboration

The strong interest in the transport sector is tied to a maturity of the technology sufficient to allow it to become the flywheel of the market. With 21 strategies out of 26 that identified at least one support policy, this is, by far, the most discussed sector. Within the sub-sector Transport, road vehicles have monopolized a good share of the interest, leaving less space for rail, shipping and aviation.

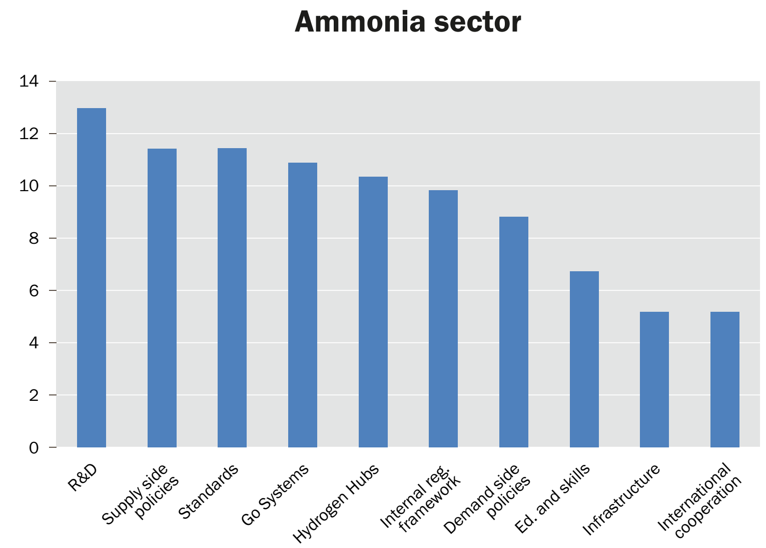
A high presence of Supply Side policies (e.g. public procurement, call for proposal, construction subsidies, investment support) indicates a strong will from legislators to manage the start of the market in the initial phases, rather than focusing on the demand side where the consumer has other alternatives (e.g. electric vehicles). There is also a clear and strong willingness to foster the creation of refuelling station networks (under the Infrastructure sub-category) in order to facilitate the adoption of fuel cell vehicles.
Standards are particularly focused on safety needs linked to the relatively high risk of the use of hydrogen.
Interestingly, no relevance is given to the issue of Guarantees of Origin, notwithstanding the role of hydrogen as a potential clean fuel to power transport.

Figure 20: General Policies - Use Policy Adoption (Hard-to-Abate)



Source: FEEM Elaboration

Figure 21: General Policies - Use Policy Adoption (Ammonia)

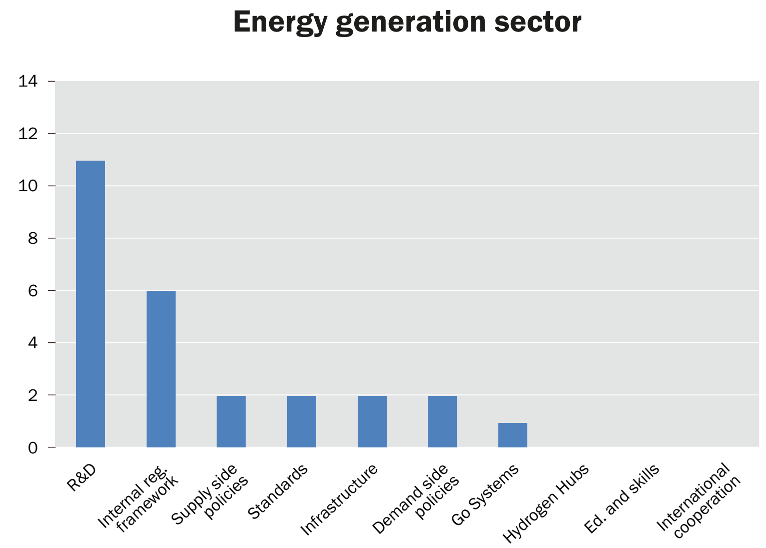


Source: FEEM Elaboration

For the Hard-to-Abate (HTA) sector the majority of Supply Side policies are financial: tax credits, compensation mechanisms (CO2 reduction), direct incentives. No production quotas or targets are envisaged, this leads to the hypothesis that i) there is limited readiness in the sector to be decarbonized (e.g. because of low TRL, or high costs) and ii) HTA sectors show a relatively minor interest compared, for instance, to the Transport sectors. This detached approach and limited participation in strategies (only 13 out of 26 presented policies in support of the HTA sector) is at odds with the immediately identified reputation of hydrogen in literature, as a possible green shifting tool for the sector.

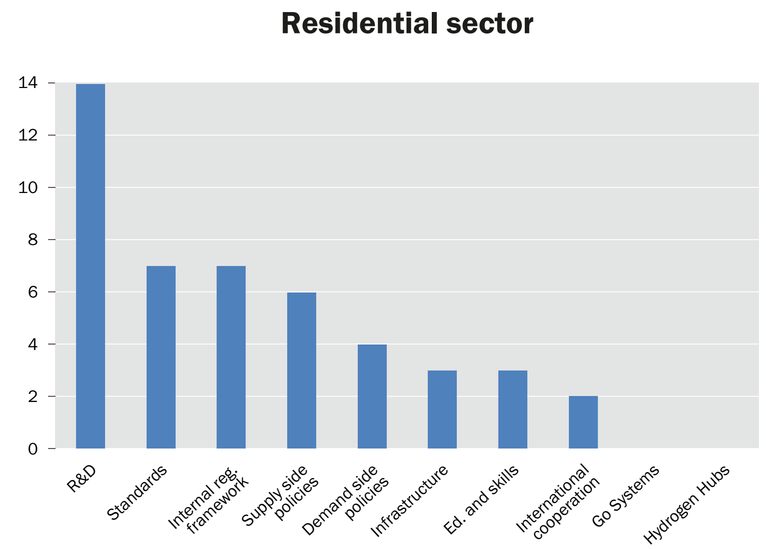
The almost total absence of policies in the ammonia sector reflects a vision of the product strictly linked to the concept of an energy carrier or chemical product, rather than an energy vector and fuel as a factor in the energy transition process. Likewise, synfuels are not relevantly assessed by current strategies.

Figure 22: General Policies - Use Policy Adoption (Energy sector)



Source: FEEM Elaboration

Figure 23: General Policies - Use Policy Adoption (Residential Generation)



Source: FEEM Elaboration

R&D leadership in the electricity generation sector reflects the willingness of governments to investigate the use of fuel cell systems and hydrogen-fired turbines to backup renewable electricity generation (e.g. ancillary services from electrolysers)

At a geographical level, the residential sector in Asia has demonstrated discreet interest, the only sector in which Demand Side policies have played a fundamental role (e.g. with incentives to popularise fuel cells in the form of tax breaks for consumers).
The issue of hydrogen transportation and storage for residential heating (via fuel cells or blending) is currently not being addressed in the strategies.

06

Country-specific indicators

In this section, two indicators are presented to further corroborate our qualitative analysis at country level, the Internal Coherence Index and the Interest Score. Both metrics aim at aggregating non-homogeneous data to allow for cross-comparison among different jurisdictions. The aim is to try to derive common traits and patterns in the way national strategies address the deployment of hydrogen in the long term.

6.1 Internal Coherence Index

The analysis of the strategies is complemented by an index specifically elaborated to evaluate the objectives of the documents in terms of the measures in their support. We call this metric the “Internal Coherence Index”. The construction of this indicator is based on three fundamental phases: i) identification of the transversal objectives across the majority of strategies, ii) creation of a consistency assessment system that returns a score, iii) attribution of a scale of qualitative description (high, medium and low, all represented by different colours) of internal coherence based on the score.
The Internal Coherence is computed at country level, and therefore does not include single states within federal entities.

A more in-depth elaboration follows:

1. The transversal objectives identified are:
    - Willingness to export;
    - Hydrogen vehicles deployment;
    - Blending of hydrogen in the grid;
    - Production objective;
    - Consumption objective;
    - Synfuel and ammonia deployment (use and production).
2. The consistency assessment system is based on four attributes. These attributes are common to all identified transversal objectives and behave as dummy variables. Each attribute, if present, gives a point of coherence to the objective under consideration. The internal coherence of each objective can therefore vary from zero to four. The absence of an objective in a strategy does not influence the internal coherence of the entire strategy that is calculated as the average of the coherence across the objectives. The attributes that have been considered as discriminating to obtain an internal coherence score are:
    - Objective Presence (OP) (returns 1 if the transversal objective is included in the strategy. This is the minimum attribute to achieve the lowest level of coherence in the objective);
    - Numerical Target (NT) (returns 1 if a quantitative or numerical target is defined, e.g. number of fuel cell vehicles);
    - Funds Allocation (FA) (returns 1 if monetary funds are allocated, e.g. €X million for the deployment of synfuels);
    - Presence of Policies (PP) (returns 1 if specific policies are set on transversal objective, e.g. supply or demand side incentives).
3. The qualitative description scale associating the numerical score with an internal consistency level is divided into:
    - Low level for a score between 1 and 1.99 (🔴);
    - Medium level for a score between 2 and 2.99 (🟡);
    - High level for a score between 3 and 4 (🟢);
    - Absence of objectives for a score equal to 0 (/).

Table 1 below shows the Internal Coherence index of each transversal objective, complemented by the overall average Internal Coherence index (average) of the strategy under consideration.

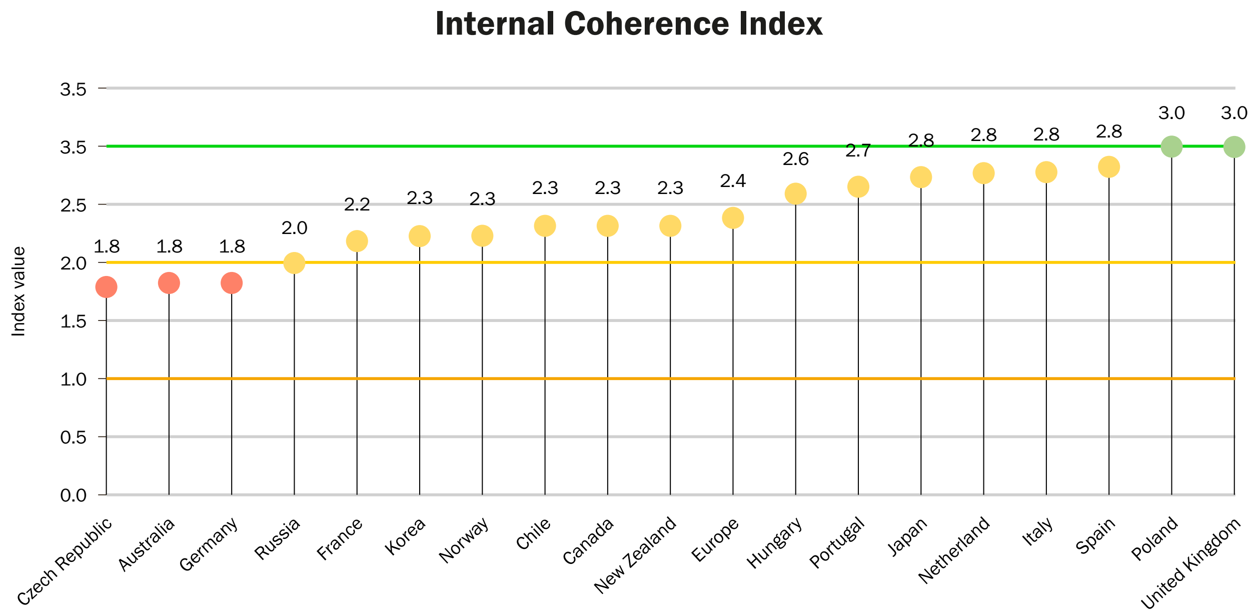
Table 1: Internal coherence index table

Country/Goal	Willingness to export	Hydrogen vehicle deployment	Blending	Production objective	Consumption objective	Synfuel and ammonia deployment (use and production)	MEAN OVERALL INTERNAL COHERENCE
Japan	/	🟢	/	🟢	🟢	🟡	🟡
Spain	🟡	🟢	🟡	🟢	🟢	🟡	🟡
Australia	🟡	🟡	🟡	🔴	🟡	🟡	🔴
France	/	🟡	🔴	🟢	🟡	🟡	🟡
Chile	🟡	🔴	🟢	🟢	🟢	🟡	🟡
Italy	/	🟢	🟡	🟢	🟢	🔴	🟡
Canada	🟡	🟢	🟢	🟡	🟢	🔴	🟡
Europe	/	🟢	🔴	🟢	🟢	🔴	🟡
Portugal	🟡	🟢	🟡	🟢	🟢	🟡	🟡
Norway	/	🟡	/	🟡	🟢	🟡	🟡
Netherlands	/	🟢	🟢	🟢	🟢	🟡	🟡
Korea	/	🟢	/	🟡	🟢	🔴	🟡
Germany	🔴	🟡	🟡	🟢	🟡	🔴	🔴
Russia	🟡	🟡	/	🟡	🟡	/	🟡
Poland	/	🟢	🟢	🟢	🟢	🟡	🟢
New Zealand	🟡	🟢	🟢	🟡	🟢	🔴	🟡
United Kingdom	🟡	🟢	🟢	🟢	🟢	🔴	🟢
Hungary	/	🟢	🟢	🟢	🟢	🔴	🟡
Czech Republic	/	🟡	🔴	🟢	🟡	🔴	🔴

Source: FEEM Elaboration

Figure 24 provides a ranking of countries based on the overall Coherence Index. It is not straightforward to derive any clustering and/or conclusions based on year of publication of the strategy, level of economic development, geography or maturity of the energy system (e.g. installed electricity capacity, penetration of renewables, status of the power and gas grids).

Figure 24: Coherence Index – Ranking of Countries



Source: FEEM Elaboration

According to this approach, only 2 out of 26 strategies feature a high level of internal coherence, the majority scores a medium level and 3 present a low level of internal coherence. These results corroborate the findings that hydrogen strategies are envisaged at a broad level, and even pioneering countries have not presented a precise and consistent long-term plan.

At the same time the will to expand knowledge of the issue and postpone funding commitments could be the key to interpreting these results. The trend towards highly generic strategies leading to a low level of internal coherence may be due to a relatively limited understanding of the way to deploy hydrogen.

6.2 Interest Score

The Interest Score is another metric devised to assess strategies at country level. Similarly to the Internal Coherence Index, the Interest Score does not include single states within federal entities.

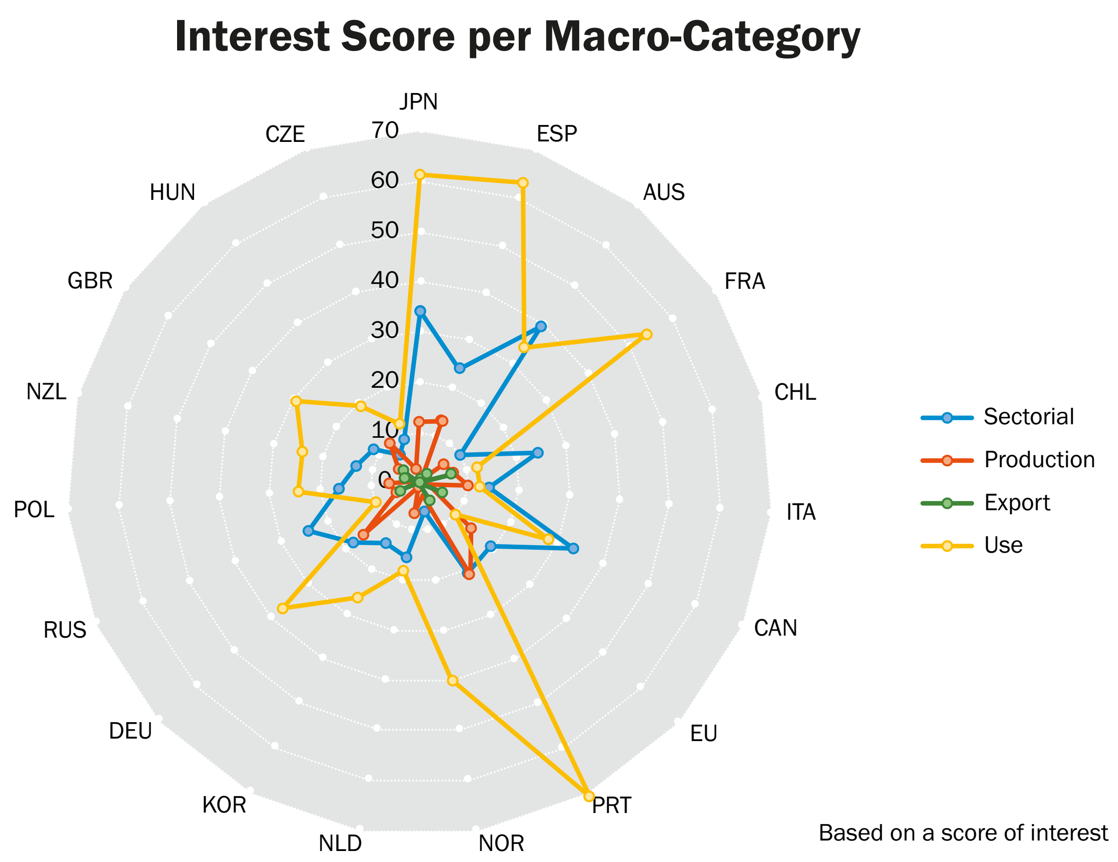
This value has been identified for each country in order to calculate the “interest”, defined in terms of level of attention and commitment, for each of the above-mentioned macro-categories (i.e. Sectorial, Production, Export and Use). We assessed how countries willing to steer their strategy in a specific area tend to leverage and combine the Policy Types defined in the previous section, i.e. i) General Policies, ii) Numerical Targets and iii) Financial Policies.

We therefore considered the following computation:

Interest Score=n° of General Policies+n° of Numerical Targets+n° of Financial Policies

Figure 25 below provides a rendering of the Interest Score along the four macro-categories.

Figure 25: Interest Score by macro-category



Source: FEEM Elaboration

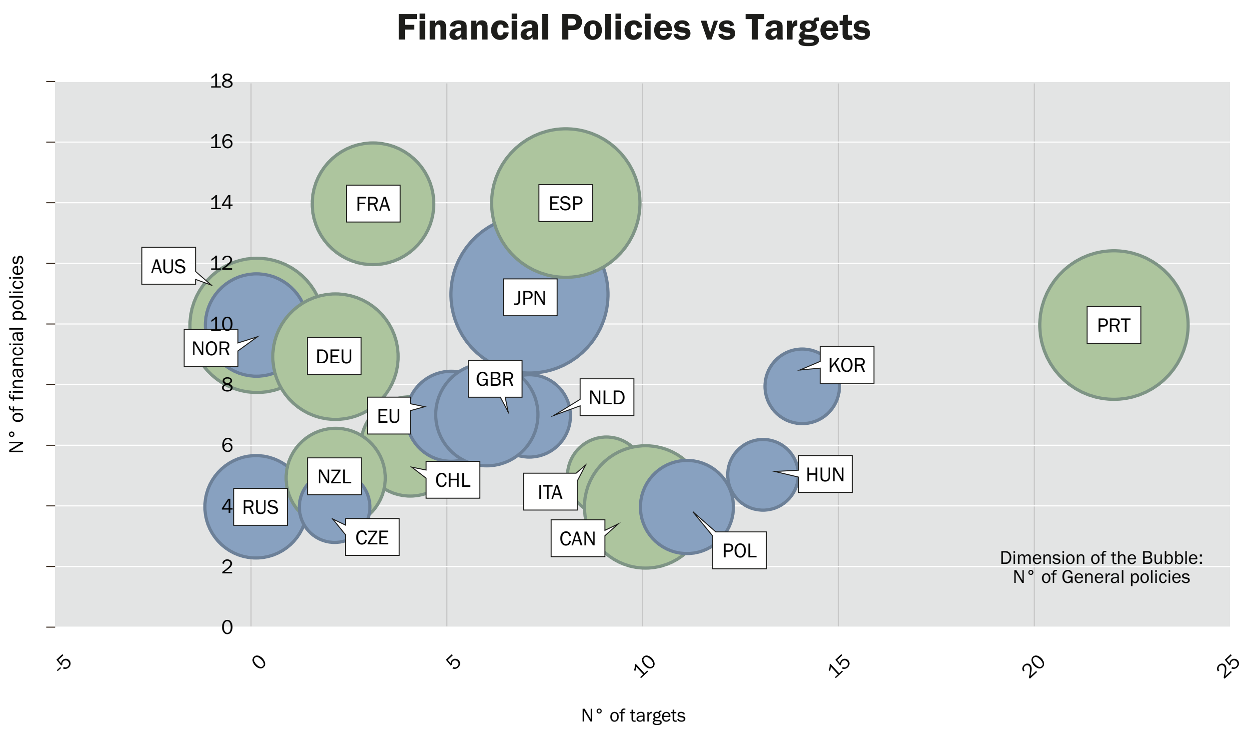
The results show a clear tendency of strategies to approach the topic of hydrogen from the side of its uses, with peaks of interest in countries such as Japan, France, Spain and Portugal. Japan in particular declared a willingness to base its hydrogen economy on imports, while the latter countries expressed, more ambiguously, an interest on the production side. Spain and Portugal also declared that they want to be exporters of green hydrogen. This is also true for other countries, such as Saudi Arabia, the United Arab Emirates and Oman, currently not included in the scope of this report, that have announced themselves as future green hydrogen exporters.

Countries such as Russia, Italy, Chile and Czech Republic, on the other hand, present a low score. This might be due, in the case of Russia and Italy, to the lack of definition of documents still in the draft phase.

Aggregated results, however, indicate a general imbalance of approach by all strategies: the risk is of a distorted start of the market, providing many solutions for the uses and little progress on the production side. Similarly, the pressure of having to demonstrate commitment towards the reduction in CO2 emissions may have affected the interest shown for uses where it would be more immediate and identifiable compared to other categories, such as production and exports.

The great heterogeneity and misalignment of strategies is also displayed in Figure 26 below, plotting financial policies vs numerical targets for each country. The size of the bubbles represents the total number of General policies, the colour whether the strategy is green or not.

Figure 26: Financial policies vs Targets



Source: FEEM Elaboration

Ideally, the upper-right quadrant would represent a fully-fledged and defined strategy, addressing multiple targets and paving the way to their achievement by providing a suitable framework of incentives and available funds. As seems evident, this is never the case, with Portugal representing a relevant outlier in this analysis. On the other hand, strategies are mainly concentrated in the bottom quadrants, reflecting i) the long term vision of the approach to hydrogen, with a general tendency to delay costly decisions to the future and ii) a potential lack of clarity and commitment on the way to kick-off the market and move forward.

07 Much ado about nothing? Our conclusions

The path to energy transition is long and not without considerable difficulties. Hydrogen will be able - and, in some cases, will be required - to play a significant role in the process. The extent to which this new energy carrier will shape our future will be a field of study for years to come. For now, this analysis has attempted to examine the approach of those countries that have published a national hydrogen strategy. The focus was on measures and policies in support of hydrogen, taking into account the targets and objectives that these countries have set themselves. The analysis produced interesting results related to a still unripe development of the hydrogen economy.

On the production side, more than half of the sample explicitly declared support only for green hydrogen. The remainder, while not stating a clear position, has proposed markedly unbalanced measures in support of it. Blue hydrogen remains, in all strategies, very marginal, represented only in the R&D policies of the macro-category Production. It should be remembered that, to date, blue hydrogen is still the cheapest solution for the production of decarbonised hydrogen, therefore, a lack of interest in it, and consequently the favour that green hydrogen enjoys, could be a symptom of a willingness to accelerate an already highly risky process rather than relying on a safer and more gradual approach.

At the sectorial level, there is a general and overriding need to understand the effective potential, risks, limits and benefits of this new energy carrier. All this emerges from a desire for international collaboration, which is particularly focused on pilot projects or study programmes, and from the strong presence of R&D policies in every identified macro-category, sector and sub-sector. These strong concerns are reflected in the reticence of most strategies to set clear numerical targets and, above all, to identify budgets for funds to allocate to the cause. At the same time, it is clear that it is difficult to define priority areas for targeted funding without risking ineffective financial outlays to support confused objectives. It is this concatenation of characteristics which then leads to average internal coherence indices and to a lack of specificity in the strategies; signs that governments are still moving in unknown territory.

Exports have been an important topic of discussion within the strategies, more than half of the countries state that they want to export hydrogen in what seems to be a global market with a topology similar to oil and gas markets. It is necessary, however, to compare the data of this analysis that indicate a strong preference for the production of green hydrogen. This is, perhaps, the most contradictory result of the report. The production of green hydrogen requires large amounts of renewable energy to be dedicated to the process of electrolysis, the latter, not only requires a high endowment of natural resources, but also a sufficiently high surplus of electrical generation capable of covering demand for all other uses, other than that of electrolysers. The data collected show that only some countries, such as Canada, Australia and Chile declare that they want to focus their export strategy on the potential of renewable electricity generation, given the national endowments, in particular of Australia and Canada, they already have sufficient renewable generation capacity for them to become top hydrogen exporters in the medium term. As can be seen from the first column of the table showing the internal coherence index, no country has achieved a good level of internal coherence with regard to export targets. What is most puzzling is the general willingness to prepare for the export of green hydrogen at a time when there is no structured market for this carrier, let alone a solid production capacity. At the same time, and in contrast with these statements, there is the almost total absence of any mention of the logistics side (transport and storage) necessary for the emergence of a hydrogen economy and, especially, for a well-structured export market. The only hints in this regard are present in Infrastructure development policies which, however, often incorporate plans to expand a hydrogen distribution network (refuelling stations for road vehicles often omitting large-scale transport and storage).

In the macro-category Use, however, in addition to the Transport sector, and especially the sub-sectors Buses, Trucks, Light vehicles and refuelling stations, there are no additional measures to support hydrogen in sectors where the need for decarbonisation is more evident and less immediate to realise (e.g. Shipping, Hard-to-abate, Energy generation). Moreover, there is no significant confirmation regarding the concept of sector coupling for which, hydrogen, can be the fundamental player given its ambivalent uses in the production of electricity and thermal energy. The strategies have focused, as far as the field of uses is concerned, on sub-sectors of easier and immediate decarbonisation (the injection of hydrogen in the gas grid) and also other technologies where there is direct, and sometimes stronger, competition in electrification for the transport sector).

In the light of the results of this analysis, it is clear that the road ahead will be challenging and the battles at the heart of the hydrogen debate are numerous. The national strategies examined here have the merit of directing the will of the individual countries on an issue of great importance, but at the same time, do not definitively meet the need for the sound, coherent, medium and long-term plans essential for the emergence and prosperity of a hydrogen economy.

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Annexes

12.1 Variables composing the structure of the dataset

Categorical variables

Pol: Policy
- **G:** General
- **F:** Financial
- **T:** Target

Foc: Focus
- **Green:** Green hydrogen
- **Prod:** Production
- **Exp:** Export (Export focus of the strategy)
- **Use:** Use
- **Sec:** Sectorial (whole value chain)

Y: year (target)
- **1°:** first year
- **2°:** second year

Aggr: Aggregate (Union of the sub-categories)
Funds: Name of the specified fund
PP: Policies presence
FA: Funds allocation
OP: Objective presence

Quantitative variables

Mon: Money (Expenditure allocated for support)
Now: Current hydrogen (use, produced, exported)
Target: Hydrogen use targets (of use, of production, of export)
Num: N° of policies adopted

The combination of more of these variables structures the dataset (e.g. Exp_Pol_T: dummy variable reflecting the presence of a policy target in the export category)

These represents the common variables applied up to the level of all subcategories of uses described in Figure 18 (e.g. Tr_Bus_T_2°Y: year variable reflecting the second target year of a specified numerical target that a strategy individuated in the sector Transport and sub-sector Bus).

12.2 Demand and Supply side policies

Demand Side policies

- Purchase subsidies
- Tax exemptions
- Incentives schemes on demand side
- Fee discount and exemptions
- Buying incentives
- Compensation mechanism (CO2 reduction based)

Supply Side policies

- Increase popularisation
- Investment support
- Support of deployment and assistance mechanism
- Call for proposals
- Incentives schemes on supply side

- Green hydrogen quotas
- Seed funding
- Construction subsides
- Blending obligation
- Consortium
- Compensation mechanism (CO2 reduction based)
- Public procurement

12.3 Descriptive statistics

Statistics referred to all the strategies, related to the graphs present in the report.

Table 2: Statistics

Total consumption per capita (incl. non conv.) (2019) (toe/cap)	
Mean	3.838024
Standard error	0.388738
Median	3.5302
Standard deviation	1.602807
Variance	2.568989
Minimum	2.0218
Maximum	8.0254
Sum	65.2464

Source: FEEM Elaboration on Enerdata

Table 3: Statistics

CO2 emissions from fuel combustion (2018) (million tonnes of CO2)	
Mean	402.4918
Standard error	100.7184
Median	305.7477
Standard deviation	415.2727
Variance	172451.4
Minimum	31.51076
Maximum	1587.024
Sum	6842.36

Source: FEEM Elaboration on Enerdata

Table 4: Statistics

CO2 emissions / GDP using purchasing power parities (2018) (kgCO2 / US dollar (2015 prices)	
Mean	0.202412
Standard error	0.02239
Median	0.165
Standard deviation	0.092315
Variance	0.008522
Minimum	0.106
Maximum	0.432
Sum	3.441

Source: FEEM Elaboration on Enerdata

Table 5: Statistics

GDP US$ at purchasing power parity per capita (2018) (kus$ppp)	
Mean	43.05934
Standard error	2.692843
Median	42.1938
Standard deviation	11.10287
Variance	123.2738
Minimum	24.763
Maximum	67.6402
Sum	732.0087

Source: FEEM Elaboration on Enerdata

Table 6: Statistics

CO2 per inhabitant (CO2 from fuel combustion) (2019) (tCO2/cap).	
Mean	7.461271
Standard error	0.761519
Median	6.7266
Standard deviation	3.139823
Variance	9.858486
Minimum	4.3403
Maximum	15.2582
Sum	126.8416

Source: FEEM Elaboration on Enerdata

Per capita emissions by sector (2018) (kgCO2 / capita): tables divided per sector.

Table 7: Statistics

Electricity and heat production	
Mean	2788.176
Standard error	508.2249
Median	1799
Standard deviation	2095.465
Variance	4390973
Minimum	362
Maximum	7399
Sum	47399

Source: FEEM Elaboration on IEA

Table 8: Statistics

Other energy industry own use*	
Mean	701.2941
Standard error	216.4552
Median	318
Standard deviation	892.4676
Variance	796498.5
Minimum	111
Maximum	3308
Sum	11922

Source: FEEM Elaboration on IEA

Table 9: Statistics

Manuf. industries and construction	
Mean	1081.294
Standard error	112.6931
Median	1161
Standard deviation	464.6455
Variance	215895.5
Minimum	481
Maximum	1867
Sum	18382

Source: FEEM Elaboration on IEA

Table 10: Statistics

Transport	
Mean	2200.059
Standard error	246.2229
Median	1816
Standard deviation	1015.203
Variance	1030637
Minimum	1389
Maximum	5184
Sum	37401

Source: FEEM Elaboration on IEA

Table 11: Statistics

of which: road	
Mean	1926.471
Standard error	192.954
Median	1705
Standard deviation	795.5699
Variance	632931.4
Minimum	1070
Maximum	4120
Sum	32750

Source: FEEM Elaboration on IEA

Table 12: Statistics

Residential	
Mean	636
Standard error	97.50592
Median	666
Standard deviation	402.0272
Variance	161625.9
Minimum	32
Maximum	1401
Sum	10812

Source: FEEM Elaboration on IEA

Table 13: Statistics

Commercial and public services	
Mean	305.6471
Standard error	44.81965
Median	279
Standard deviation	184.7962
Variance	34149.62
Minimum	104
Maximum	883
Sum	5196

Source: FEEM Elaboration on IEA

Statistics referred to the European strategies only, related to the graphs present in the report.

Table 14: Statistics

Total consumption per capita (incl. non conv.) (2019) (toe/cap)	
Mean	3.361691
Standard error	0.33787
Median	2.7231
Standard deviation	1.120587
Variance	1.255715
Minimum	2.1137
Maximum	5.3107
Sum	36.9786

Source: FEEM Elaboration on Eneredata

Table 15: Statistics

CO2 per inhabitant (CO2 from fuel combustion) (2019) (tCO2/cap). EU	
Mean	6.485236
Standard error	0.711705
Median	5.2614
Standard deviation	2.360459
Variance	5.571767
Minimum	4.3403
Maximum	11.8894
Sum	71.3376

Source: FEEM Elaboration on Eneredata

Table 16: Statistics

Per capita electricity consumption (2019) (kWh/cap)	
Mean	6966.555
Standard error	1668.616
Median	5155.006
Standard deviation	5534.172
Variance	30627062
Minimum	3948.132
Maximum	23393.22
Sum	76632.11

Source: FEEM Elaboration on Eneredata

12.4 Summary Tables of Strategies

Category / Country	Japan	Spain	France	Chile	Italy
Pubblication Year	2019	2020	2020	2020	2020
Title and Document	The Strategic Road Map for Hydrogen and Fuel Cells	Hoja de Ruta del Hidrógeno	Stratégie nationale pour le développement de l'hydrogène décarboné en France	Green hydrogen strategy	Strategia Nazionale Idrogeno Linee Guida Preliminari
Typology of document (draft or strategy)	Strategy	Strategy	Strategy	Strategy	Draft
Time horizon of the strategy	2050	2050	2030	2050	2050
Investment commitment	JPY 699.6 B by 2030	EUR 8.9 B	EUR 7.2 B	USD 50 M for 2021	10 B euros
Strategy type (Green / Other)	Other	Green	Green	Green	Green
Strategy focus	Uses	All value chain	Uses	Production	All value chain
Internal coherence	●	●	●	●	●
Willingness to export	no	yes	no	yes	no
Numerical targets	**2030** -60% reduction CO2 emissions in production with respect to grey H2 -800,000 units of light vehicles -10,000 forklifts -1,200 buses -320 refuelling stations -5,3 M fuel cells"	**2030** -4.6 Mt of CO2 reduction -4 GW of electrolysers -7,500 light vehicles -200 buses -150 refuelling stations -2 trains -25% of green H2 in HTA "	**2030** -60 Mt of CO2 reduction -6.5 GW of electrolysers -150,000 direct and indirect jobs created "	**2030** -25 GW of electrolysers capacity -200 Kt of green H2 produced per year -2 hydrogen valleys -20% blending in the grid"	**2030** -8 Mt of CO2 reduction -100,000 fixed jobs created -200,000 temporary jobs created -5 GW of electrolysers capacity -20% of green H2 penetration in uses (2% in trucks) -Half of non electrified train lines converted to H2 -2% of blending in the grid"

Category / Country	Europe	Portugal	Norway	Netherlands	Korea	Germany	Russia	Poland
Pubblication Year	2020	2020	2020	2020	2019	2020	2020	2021
Title and Document	A hydrogen strategy for a climate-neutral Europe	Estrategia nacional para o hidrogênio	The Norwegian Government's hydrogen strategy	Netherlands Government Strategy on Hydrogen	Hydrogen Economy: Roadmap of Korea	The National Hydrogen Strategy 2020	Правительство российской федерации	Polskiej Strategii Wodorowej do roku 2030 z perspektywa do 2040 r.
Typology of document (draft or strategy)	Strategy	Strategy	Strategy	Strategy	Strategy	Strategy	Strategy	Strategy
Time horizon of the strategy	2050	2050	2050	2050	2040	2030	2025	2040
Investment commitment	EUR 76 B	EUR 7 B	NOK 200 M for 2021	EUR 70 M/year	n.a.	EUR 9 B	n.a.	PLN 30.6 B
Strategy type (Green / Other)	Other	Green	Other	Other	Other	Green	Other	Other
Strategy focus	All value chain	All value chain	All value chain	All value chain	Uses	All value chain	All value chain	All value chain
Internal coherence	●	●	●	●	●	●	●	●
Willingness to export	no	yes	no	no	no	yes	yes	no
Numerical targets	**2030** -40 GW electrolysers capacity -40 GW electrolysers capacity in Europe neighbourhood with import possibilities -10 Mt of decarbonised H2 produced per year"	**2030** -2 GW of electrolysers capacity -5% of final consumption penetration (of transport as well) -1,000 light vehicles -500 trucks -750 busses -100 refuelling stations -5% of final consumption in shipping -5% of final consumption in HTA -15% of blending in the grid"	n.a.	**2030** -4 GW of electrolysers -300,000 vehicles (not specified) -50 refuelling stations -20% blending in the grid"	**2040** -27 Mt of CO2 reduction -23 Mt of fine dust reduction -5% of final consumption penetration -2.9 M vehicles (not specified) -80,000 taxis -30,000 trucks -40,000 busses -1,200 refuelling stations -8 GW of fuel cells (industrial) -2.1 GW of fuel cells (residential)"	**2030** -14 TWh2 of green H2 production "	n.a.	**2030** -2 GW of electrolysers -6.415 GWh a year prduced with H2 -193.643 t of H2 produced -5 hydrogen valleys -2,000 busses -10% blending in the grid"

Category / Country	United Kingdom	Hungary	Czech Republic	New Zealand	Australia	Australia - Queensland	Australia - South Australia	Australia - Tasmania	Australia - Western Australia	Australia - New South Wales	Canada	Canada - Alberta	Canada - Ontario
Pubblication Year	2021	2021	2021	2019	2019	2019	2019	2020	2019	2020	2020	2020	2020
Title and Document	UK Hydrogen Strategy	Hungary's national hydrogen strategy	The Czech Republic's Hydrogen Strategy	A vision for hydrogen in New Zealand: Green Paper	Australia's national hydrogen strategy	Qeensland hydrogen industry strategy	South Australia's Hydrogen Action Plan	Tasmanian Renewable Hydrogen Action Plan	Western Australian Renewable Hydrogen Strategy	Net Zero Plan Stage 1: 2020-2030	Hydrogen strategy for Canada	Natural Gas Vision and Strategy	Ontario Low-Carbon Hydrogen Strategy
Typology of document (draft or strategy)	Strategy	Strategy	Strategy	Draft	Strategy	Strategy	Strategy	Strategy	Strategy	Draft	Strategy	Draft	Draft
Time horizon of the strategy	2050	2040	2050	2030	2050	2030	2030	2030	2040	2030	2050	2050	2050
Investment commitment	> GBP 4 B	HUF 135 B by 2030	n.a.	n.a.	AUD 1.3 B	USD 19 M	n.a.	AUD 50 M	AUD 10 M	n.a.	CAD 25 M by 2025	n.a.	n.a.
Strategy type (Green / Other)	Other	Other	Other	Green	Green	Green	Green	Green	Green	Other	Green	Other	Other
Strategy focus	All value chain	All value chain	All value chain	All value chain	Production	Production	Production	Production	Production	Uses	Production	Production	All value chain
Internal coherence	🟢	🟡	🔴	🟡	🔴	🟡	🔴	🟡	🟡	🔴	🟡	🔴	🔴
Willingness to export	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes	yes	no
Numerical targets	**2030** -9,000 jobs created -5 GW of low carbon H2 -4,000 busses (EV and FCV) -20% blending in the grid"	**2030** -20,000 t/year low carbon H2 production -16,000 t/ year green H2 production -240 MW electrolysers -10,000 t/year H2 used in transport -130,000 of CO2 emissions reduced -4,800 vehicles (not specified) -40 refuelling stations -20,000 t/year of low carbon H2 used in HTA -4,000 t/year of green H2 used in HTA -95,000 t of CO2 emissions avoided in HTA -2% blending in the grid"	**2035** -284 kt/year of H2 produced"	**2030** -200 refuelling stations -20% blending in the grid"	n.a.	**2030** -Australia's top producer of green H2 -10% blending in the grid"	**2030** -100% green hydrogen producer"	**2030** -10% blending in the grid"	**2040** -10% blending in the grid"	**2030** -10% blending in the grid"	**2030** -45 Mt of CO2 reduction -6% of penetration in uses 2050 -160,000 trucks -60,000 busses -30% of penetration in the energy sector -50% of blending in the grid"	n.a.	n.a.

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