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Short Communication

Incentives and legal barriers for power-to-hydrogen pathways: An international snapshot

Francesco Dolci [a], *Denis Thomas* [b], *Samantha Hilliard* [c], *Carlos Fúnez Guerra* [d], *Ragnhild Hancke* [e], *Hiroshi Ito* [f], *Mathilde Jegoux* [g], *Gijs Kreeft* [h], *Jonathan Leaver* [i], *Marcus Newborough* [j], *Joris Proost* [k], *Martin Robinius* [l], *Eveline Weidner* [a], *Christine Mansilla* [m,*], *Paul Lucchese* [m]

[a] European Commission, Joint Research Centre (JRC), Petten, Netherlands
[b] Hydrogenics
[c] Clean Horizon, France
[d] Centro Nacional Del Hidrógeno, Spain
[e] IFE, Norway
[f] AIST (Advanced Industrial Science and Technology), Japan
[g] Engie, France
[h] Groningen University, the Netherlands
[i] Unitec Institute of Technology, New Zealand
[j] ITM Power, UK
[k] Université Catholique de Louvain, Division of Materials and Process Engineering, Belgium
[l] Forschungszentrum Jülich GmbH, Institute of Electrochemical Process Engineering (IEK-3), Germany
[m] CEA, Université Paris Saclay, France

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ABSTRACT

Rendering the energy system more sustainable can only be achieved through a combination of low-carbon energy production, energy efficiency, and coupling of energy sectors. In this context, Power-to-Hydrogen concepts for managing supply and demand, providing seasonal storage, and being the linking element between different sectors (electricity generation, gas grids, transport and industry), has attracted significant interest during the last decade. However, the deployment of technology is subject to legal barriers, which may differ from one region to another. On the contrary, there may be incentives to facilitate market introduction of a new technology.

In this paper, an international network of experts under the umbrella of Task 38 of the International Energy Agency's Hydrogen Technology Collaboration Programme assesses the legal framework in ten countries regarding power-to-hydrogen applications. The most

* *Corresponding author*. CEA Saclay, DAS I-tésé, Bat. 524, 91191 Gif-sur-Yvette Cedex, France.
E-mail address: christine.mansilla@cea.fr (C. Mansilla).
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Incentives
Legal
Sector coupling

frequently considered pathway, from a legal standpoint, is using hydrogen for mobility applications. Only a few countries are implementing legal frameworks for diverse hydrogen applications.
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Introduction

Making the energy system more sustainable, with a significant reduction of CO_2 emissions in accordance with the Paris COP21 agreement [1], is the guiding principle of national energy policies. 175 of 197 Parties have ratified the COP21 agreement [1], with the following goals: to limit global warming within 2 °C above pre-industrial levels and aim to limit it to 1.5 °C; set global emissions to collectively peak as soon as possible; and to reduce emissions in accordance with the best available science. Developing countries will get support for pursuing these targets and specific climate actions developed by Signing Parties. In Europe for instance, the climate goals are threefold [2]: i) At least 20% (2020), 40% (2030) and 80% (2050) cuts in greenhouse gas emissions should be achieved compared to 1990 levels; ii) At least 20% (2020) and 27% (2030) of total energy consumption from renewable energy should be reached (the new Renewable Energy Directive set a 32% target for renewable energy by 2030), and iii) at least 20% (2020) and 27% (2030) increase in energy efficiency attained (the new Renewable Energy Efficiency Directive set a 32.5% target for energy savings by 2030).

Such a transformation is demanding and all possible means need to be leveraged, i.e. a combination of low-carbon energy, energy efficiency, and the coupling of energy sectors [3]. The complexity of this decarbonisation challenge is even further increased by the necessity to uphold a sufficient level of security of supply in energy systems with high shares of variable renewable energy production. Keeping the grid stable is becoming increasingly difficult due to the expansion of renewable energy in the energy mix. Solutions such as creating a transmission super-grid, smart grids and demand management, or back-up capacity implementation could assist in overcoming this issue; however, new measures that go beyond increasing transmission and distribution capacity and flexible generation or consumption will need to be introduced to manage the grid as the level of renewable energy sources is increased. In this context, hydrogen systems are part of the global discussion on energy system modernization [4]. The application of Power-to-Hydrogen concepts for managing demand, providing seasonal storage, and linking element between different sectors (electricity generation, gas grids, transport and industry), has attracted significant interest during the last decade.

Power-to-Hydrogen (PtH) can support the integration of fluctuating renewable sources of power generation by converting electricity to hydrogen. Power-to-Hydrogen systems can be used on- or off-grid and serve as a measure to avoid curtailment of electricity generation, to provide grid balancing services or enable more renewable electricity to enter into new applications in the form of a green gas, green chemical and green fuel. This concept is made possible by the characteristics of hydrogen production through electrolysis to quickly adjust its power consumption: electrolysers can reach full load operation in a few seconds [5]. In addition, chemical energy carriers such as hydrogen can also facilitate large-scale long-term storage due to the comparatively low storage costs.

Further down the value chain, hydrogen can be deployed in a large portfolio of applications – termed as “Hydrogen-to-X” (HtX). Possible applications include hydrogen for fuel cells in transport (HtF-H2); whereas, other transport pathways using hydrogen to produce synfuels such as methanol or biofuels (HtF-S), or gas fuels for transport (HtF-G)), “green” gas through methanation (PtG-M) or direct blending of hydrogen with natural gas (PtG-H2) [6], in industry e.g. refineries (HtI), heat generation (HtQ), production of chemicals (HtCh), and for re-electrification into the electricity grid or remote areas (HtP). Thereby, hydrogen links the power sector to other energy intensive sectors (heat, transport, industry). This obliges consideration of an integrated energy system with interconnections between different energy carriers [7].

The total value chain, from power generation to the use of hydrogen in diverse applications, is commonly termed Power-to-X. An attempt at precisely categorizing the different PtH – HtX pathways was presented in Dickinson et al. (2017) [8].

In this paper, an international network of experts under the umbrella of Task 38 of the International Energy Agency's Hydrogen Technology Collaboration Programme [9] carries out an assessment of the legal framework related to Power-to-Hydrogen pathways in ten countries: Belgium, France, Germany, Italy, Japan, New Zealand, Norway, Spain, The Netherlands, and the United Kingdom. Only national legislation is considered, as the review does not examine at a regional scale.

The following section focuses on the incentives. When none are mentioned, it means that none current exist. Section on Legal barriers then provides an overview of the legal barriers.

Incentives

Promoting low-carbon hydrogen production (PtH)

Power-to-Hydrogen pathways can contribute to the transition towards a low-carbon energy system, provided of course that hydrogen is produced in a sustainable way. Indeed, today 96% of hydrogen is produced from fossil fuels [10]. To ensure the low-carbon origin of hydrogen, some renewable or green hydrogen certification mechanism should be defined and established. In Europe, there are some on-going initiatives regarding certification. The project CERTIFHY aims at establishing the first Green Hydrogen Guarantee of Origins (GOs) that will be available for sale EU-wide [11]. The work distinguishes between renewable and low-carbon origins. Under the new EU Renewable Energy Directive, the role of renewable hydrogen is now explicitly acknowledged [12]. A standardisation effort is also ongoing. At the European level, the European Committee for Electrotechnical Standardization (of the European Committee for Standardization, CEN – CENELEC [13]) is developing a standard on Guarantee of Origin for production of hydrogen.

The situation varies for supporting policies for hydrogen production from electrolysis (PtH). In Norway hydrogen produced through electrolysis is exempt from electricity consumption taxes (not from grid tariffs though) [14]. Specific subsidies are available in the Netherlands as the Ministry of Economic Affairs established a subsidy programme for energy projects, including a specific subsidy for hydrogen-related projects (not limited to production). The maximum allowable funding is 750,000 € per project [15].

Incentives towards the use of hydrogen in the transport sector

Regarding the downstream uses of hydrogen production, the incentives vary drastically from one pathway to the other. The most favourable pathway (and the most incentivized) is the use of hydrogen in fuel cell vehicles (HtF-H2).

- Incentivizing the infrastructure deployment

First, incentives to foster the deployment of a hydrogen infrastructure (to address the well-known chicken and egg problem) are deployed by several nations.

In Italy, public incentives (EU and national) are expected to reach 47 million € in 2020 and 419 million € for 2021–2025, 40% of them being national funds [16]. In Germany, the eMobility funding programme includes a 300 million € for infrastructure [17]. The Alternative Fuel Infrastructure Directive (AFID) EU 2014/94 implementation involves the construction of 400 hydrogen refuelling stations by 2023 in Germany [17]. In Japan, half of construction costs of the HRS are subsidized regardless of the origin of the hydrogen [18]. In Norway, a national investment support program for the establishment of hydrogen refuelling stations was launched in spring 2017, where up to 40% of project costs can be covered. Technical requirements of this programme demand a minimum capacity of 200 kg H_2/day and a minimum of two fuelling nozzles, in which one should deliver at 700 bar [19]. In the Netherlands, subsidies for the deployment of hydrogen refuelling stations are provided for under the Hydrogen subsidy programme of the Ministry of Economic affairs [20]. Finally, in Belgium, excise tax is not paid on the sale of hydrogen as a transport fuel.

- Incentivizing the vehicle purchase

Still, regarding the HtF-H2 pathway, there are a number of incentives regarding fuel cell electric vehicles.

In some cases, these incentives are binding regulations. In the Netherlands, from 2035 onwards, all new passenger vehicles must be able to drive with a carbon neutral footprint [21]. Most often, the incentives consist of subsidies for vehicle purchase. Several grants are possible for electric or fuel cell electric cars. The order of magnitude is usually several thousand euros.

In Belgium, a 4000 euro grant is available in Flanders for all electric cars, but it is not applicable for companies/leasing [22]. In Germany, for electric cars (including fuel cell ones), there is a grant of 4000 €. For hybrid cars, it amounts to 3000 €. Rewards are only for cars with a list price of maximum 60,000 € (base model). The promotion lasts for a maximum total of 400,000 cars. The federal government contributes a total of 600 million €, and this cost is shared equally between the federal government and the automakers. Overall, the funding reaches 1.2 billion €. This promotion will end in 2020 [23]. In Japan, the national subsidy for fuel cell hydrogen electric vehicles is of 2.02 million JPY (i.e. 15,000 €/vehicle) [24]. It ranges from 0.1 to 0.4 million JPY for other kinds of electric cars. In France, 27% of the price of the vehicle (taxes and batteries included) is subsidised, not exceeding a maximum of 6000 €. This is granted for the acquisition of a new vehicle which emits less than 20gCO_2/km (except for hybrid vehicle which use diesel). For vehicles emitting between 21 and 60 g CO_2/km, the premium is 1000 €. There is also a diesel scrappage scheme: switching a 11-year old -or older-diesel car for a new electric car grants an extra 4000 € (or 2500 € in case it is a plug-in hybrid electric vehicle). The "L" category (Quadricycles, Motorbikes, Scooters …) has a 250 € per kWh purchase subsidy (lead battery vehicles excluded), with a limit of 1000 € or 27% of purchase price [25,26]. In Spain, electric vehicles can benefit from incentives ranging between 1100 and 15,000 €; it amounts to 5500 € for fuel cell electric vehicles [27]. In the Netherlands, for lease/company cars, the fiscal costs for the private use of zero-emission lease cars, including fuel cell electric vehicles, are limited to 4%. Petrol cars pay 22% [28,29]. In the UK, there is a government grant of £4500 (approximately 5000 €) for buyers of fuel cell electric vehicles [30].

Additionally, several countries grant an exemption (partial or total) of registration tax to electric and fuel cell electric vehicles. In Belgium, electric and plug-in hybrid vehicles are exempt from registration tax (in Flanders only) [22]. In France, there are road tax exemption and reduction of matriculation certificate fees (French "carte grise"). The reduction for a *clean engine* vehicle depends on the region [31]. In Spain and Norway, there is purchase tax exemption [32,33]. In the Netherlands, zero-emission cars are exempt from paying the registration tax. For the other kinds of cars the system is progressive, with five levels of CO_2 emissions which pay different amounts of registration tax. Plug-in hybrid cars go to level 1 (1–79 gCO_2/km) and pay 6 € per gram. For level 2 (80–106 gCO_2/km), the tariff is 69 € per gram CO_2. The final level is 476 € per gram for cars emitting 174 gCO_2/km or over [29].

There are also ownership tax exemptions (partial or total) in several countries.

In Belgium, electric vehicles pay the lowest rate of tax under the annual circulation tax in all three regions. (74 € instead of 1900€) [22]. In Italy, electric vehicles are exempted from the annual circulation tax (ownership tax) for a period of five years from the date of their first registration. After this five-year period, in many regions, they benefit from a 75% reduction of the tax rate applied to equivalent petrol vehicles [34]. In Germany, the exemption is for the first ten years for cars registered until Dec 31, 2015, then five years afterwards until Dec 31, 2020 [23]. In Norway and Spain, tax reductions also exist. In the Netherlands, exemption from motor vehicle taxes and road tax is granted for fuel cell electric vehicles [35]. Finally in New Zealand, there is a 385€ road user charge exemption, and a 44€ reduction in compulsory personal injury insurance.

Incentives towards the use of low-carbon hydrogen in the industry

There are few supporting policies for the use of green hydrogen in industry (HtI).

In France and the Netherlands replacement of fossil-fuel derived hydrogen is encouraged by tax exemptions. In France, the use of renewable hydrogen in industry has an impact on avoiding the carbon tax ("Contribution Climat-Énergie") which was 30.5€/tCO2 in 2017, and should reach a level of 100€/tCO2 by 2030 [36]. In the Netherlands, investments which result in the replacement of fossil fuels by hydrogen are deductible from the profit before being taxed up to 41.5% [37].

Incentives towards blending with natural gas

The case for Hydrogen-to-Gas pathways is peculiar (HtG). Bio-methane feed-in tariffs do exist in many countries. Bio-methane injection (in the natural gas grid) feed-in tariffs are being discussed in Flanders and Wallonia [38]. In Germany, bio-methane utilisation is eligible for feed-in tariffs only when being used for CHP [39]. In France, bio-methane feed-in tariffs were fixed in 2016 for a period of 15 years [40]. The producer will benefit from a feed-in-tariff between 46 and 139 €/MWh. In the Netherlands, for the production of energy products from biomass, operators can request a subsidy. The amount of subsidy is awarded for every kWh injected into the gas grid and covers the difference between the price of bio-methane and natural gas, with a maximum amount of 6 million € per project and a period of 12 years [41,42]. In the Netherlands, the bio-methane feed-in tariffs is 3.6 €c/kWh for first 40 GWh injected, falling to 2.1 €c/kWh for next 40 GWh, and to 1.6 €c/kWh for any remainder from sites injecting >80 GWh [43].

However some questions arise: is synthetic methane produced through the methanation pathway (HtG-M) eligible for similar feed-in tariffs? And what about direct blending of hydrogen (HtG-H2) and tariffs that respect the blend concentration? Today, none of these schemes recognize synthetic gas or hydrogen as a green gas eligible for a green gas feed-in tariff. What is more, concerning the latter, there is the additional issue of the maximum concentration of hydrogen in the hydrogen-natural gas blend. This is addressed in the following Section on Legal barriers.

Legal barriers

Regarding hydrogen production

For the production of hydrogen, regulations (especially regarding safety) are being implemented. In France, for instance, special permitting is required for hydrogen production and storage [44,45]. Hydrogen production sites "making industrial quantities" are subject to ICPE authorisation (ICPE, Installation Classée pour la Protection de l'Environnement in French, facilities classified for environmental protection), which is a binding regime. This case is under negotiation for a less constraining administrative regime for hydrogen obtained via water electrolysis. Hydrogen sites storing strictly less than 100 kg of hydrogen are not subject to administrative constraints. An ICPE declaration needs to be made if the stored quantity ranges from 100 kg to 1000 kg. An ICPE authorisation is compulsory for quantities beyond 1000 kg.

In Spain, regardless of the amount of hydrogen produced, it is necessary to process and obtain the environmental impact assessment [46] and integrated environmental authorization [47]. The Spanish legislation does not differentiate the sources of hydrogen production: they must comply with all the same environmental requirements.

These permitting regimes in France, Spain and other EU countries is to a large extent prescribed under the EU Industrial Emissions Directive under which Power-to—Hydrogen is considered an activity for the 'production of inorganic chemicals' [48]. The permitting regime for such installations does not differentiate between different hydrogen production pathways such as Power-to-Hydrogen and methane steam reforming.

Regarding hydrogen blending with natural gas

Regarding the direct injection of hydrogen in the natural gas grid, the authorized concentrations vary significantly from country to country because historically, when the existing regulations were introduced, there was no consideration of the possibility of gas grids conveying hydrogen admixtures (see Table 1). In Germany for example, there are no national legislative restrictions regarding the hydrogen content in natural gas. The limitations vary from 10 vol.-% as an admixture to below 2 vol.-% if a CNG filling stations is connected, and if no calibrated hydrogen measurement system is installed, the hydrogen content shall not exceed 0.2 vol.-% [49].

When assuming perfect gases, molar and volume percentages are equivalent. As a result, the values taken from the regulatory frameworks can be ranged to catch the rate diversity (see Fig. 1). This is a major bottleneck to develop this pathway, since even when allowed, the maximum concentration of hydrogen is low. Projects like GRHYD [50] and HyDeploy [51], which have local exemptions to inject up to 20% hydrogen, are pushing the boundary and may lead to new regulations and greater harmonisation across Europe.

Table 1 – Allowed hydrogen concentration in the gas grid, according to the countries.

	Belgium [52]	Italy [53]	Germany [54]	France [55]	Japan [18]	Spain [56]	Netherlands [57]	UK [58]
Maximum H_2 concentration allowed in the gas grid	<0.1% mol (injection up to 2% vol could be considered)	<2–3% vol (0.5% vol for bio-methane)	<10% mol (<2% mol-for CNG tanks)	6% mol	0% mol	5% mol	0.02% mol (There are plans to raise this to 0.5% mol)	0.1% mol

Regarding hydrogen use for the transport sector

There are also legal barriers related to the use of hydrogen in fuel cell vehicles.

Accuracy in hydrogen dispensing is a significant issue in several European countries, as well as homogeneously standardised connectors.

In Belgium, measurement accuracy in fuel distribution must meet specific accuracy criteria (metrology, based mainly on liquid fuels). Current technologies do not meet these criteria and therefore intermediate regulations need to be adapted to provide for payment terminals accepting bank card payments. In Germany, the allowable dispensing tolerance of 1%–1.5% is prescribed. Unfortunately, it is not possible to reach the required accuracy, therefore a derogation has been requested for the existing hydrogen refuelling stations to allow for higher tolerances [59]. In France, a decree is in preparation, for stations with storage capacities lower than 1 tonne H_2 (declaration with periodic control). Hydrogen vehicle refuelling points, or renewed refuelling points, across the EU are currently unable to meet the AFID [60] requirement concerning the deployment of ISO 17268 compliant nozzles, because such technology is not yet available commercially. The transposition of AFID Article 5, clause 2, has been implemented inconsistently across the EU with some countries requiring the use of ISO 17268 compliant nozzles (e.g. Sweden, Spain, Netherlands, UK) while others do not (e.g. France, Denmark and Germany).

Additionally, permitting procedures are required for hydrogen refuelling stations, with regard to safety considerations.

General outlook

Considering the legal barriers and incentives that were identified in this article, an attempt to characterise the legal framework for each pathway and country is carried out in Table 2.

It is worth noting that the European HyLAW project [61] is investigating the specific details of the existing legal barriers pushing back against the development of hydrogen systems in Europe.

From this table, it clearly appears that the most acknowledged pathway, from a legal standpoint, is the use of hydrogen as fuel for fuel-cell vehicles, since it benefits from general incentives for electric or low-emission vehicles. Hydrogen blending in the natural gas grids is trickier under the current regulation. Specific regulations seem to be lacking for several pathways. Some frameworks are in place, such as the one for bio-methane, but at this time it remains unclear whether this will be an opportunity for PtH pathways in the future. Incentives begin appearing for the industrial sector, which is recently gaining momentum [62].

Compared to other countries, the Netherlands seem to be implementing a global legal framework, encompassing the variety of hydrogen applications as shown in recent works and scenarios [63–67]. France seems to be on the same pathway, but industry uses do not appear in the agenda of most examined countries.

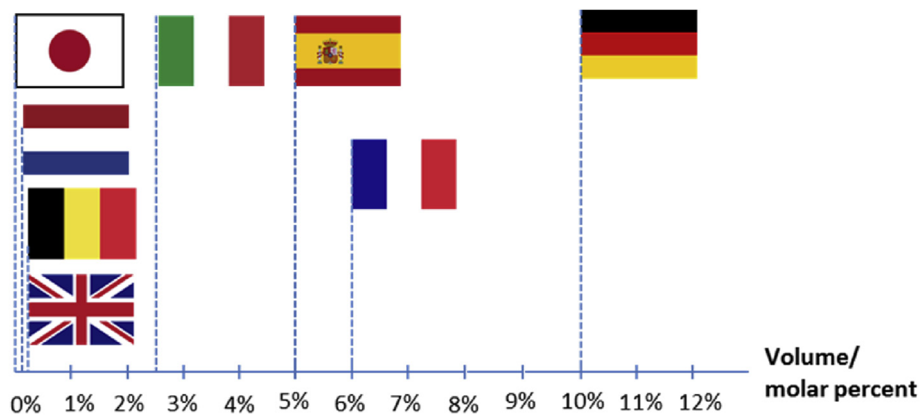

Fig. 1 – Hydrogen blending rates range.

Table 2 – Legal framework according to the pathways.

Country		BE	FR	DE	IT	JP	NZ	NO	ES	NL	UK
PtH			somehow difficult					favourable context		favourable context	
HtP										favourable context	
HtF	*HtF-H2*	favourable context	favourable context	favourable context	somehow favourable	favourable context	somehow favourable	favourable context	favourable context	somehow favourable	favourable context
	HtF-S										
	HtF-G										
HtG	*HtG-H2*	somehow favourable	favourable context	favourable context	somehow favourable	difficult context			favourable context	somehow difficult	somehow difficult
	HtG-M	somehow favourable	somehow favourable	somehow favourable						somehow favourable	
HtI			somehow favourable							somehow favourable	
HtCh											
HtQ											

favourable context
somehow favourable
somehow difficult
difficult context
no information

PtH	Power-to-Hydrogen
HtP	Hydrogen-to-Power
HtG-H2	Hydrogen-to-Gas (feed-in H2)
HtG-M	Hydrogen-to-Gas (feed-in of synthetic methane)
HtF-H2	Hydrogen-to-Fuel (Hydrogen)
HtF-S	Hydrogen-to-Fuel (liquid synfuels)
HtF-G	Hydrogen-to-Fuel (gaseous synfuels)
HtI	Hydrogen-to-Industry
HtQ	Hydrogen-to-Heat
HtCh	Hydrogen-to-Chemicals

Conclusion and policy recommendations

'Low-carbon' hydrogen (i.e. that produced through low-carbon pathways, such as water electrolysis powered with low-carbon electricity) can be used by different energy-consuming services. It has a potential role to play in the electric, gas, transport, and industrial sectors. This paper presents a review of the incentives and legal barriers in ten countries, with regard to Power-to-Hydrogen and Hydrogen-to-X pathways.

The main application specific to hydrogen for which countries have already started to develop explicit regulations is the use of hydrogen in fuel cell vehicles. A number of incentives were implemented, either for low-emission vehicles in general or specifically for hydrogen vehicles. For the pathways involving the natural gas grid, there are still barriers. Allowed injection limits for hydrogen are low, and feed-in tariffs are only implemented for bio-methane. On the other hand, incentives are beginning to appear for the industrial sector.

However, the specificity of hydrogen being a versatile energy carrier seems to be often disregarded. Only few countries are implementing legal frameworks facilitating diverse hydrogen applications. Also, the potential benefits of hydrogen production via water electrolysis in contributing to the electric system stability and greater integration of variable renewables seem neglected as well. Power-to-Hydrogen production via electrolysis is rarely promoted directly. Among the countries covered, only Norway has implemented an electricity tax exemption for hydrogen production.

From the review that was carried out, some policy recommendations can be identified:

- Promote hydrogen use with a holistic approach, by encompassing all the possible pathways (PtX):
  - o Develop incentives in the transport sector beyond the sole light passenger duty vehicles (i.e. by including trucks, trains, maritime use), and incentivize the infrastructure development jointly with the vehicle purchase;
  - o Remove the legal barriers for the blending of hydrogen with natural gas by harmonizing the blending concentrations, and set thresholds based on physical constraints [68]; acknowledge the actual greenhouse gas mitigation for gas applications by also accounting the contribution of methane leakages during processing and transport of natural gas (and implement the relevant incentives/penalties accordingly); implement support schemes as it is done for bio-methane injection;
  - o Promote the use of low-carbon hydrogen in industry by implementing adequate certificates and/or penalties;

ensure a "level playing field" for products obtained with low-carbon hydrogen;

- Promote the production of low-carbon hydrogen:
  - o Implement adequate regulations on polluting activities (e.g. carbon taxation);
  - o Acknowledge the contribution of hydrogen systems to the development of renewables (develop certificates, tax exemption for the power consumed by electrolysers (especially when hydrogen is meant to produce power, grid tariff exemption could also be considered); allow participation to ancillary services and capacity mechanisms).

Even if favourable economic conditions are met, Power-to-Hydrogen pathways will only develop provided that appropriate regulations make it possible. The attention of stakeholders must be raised on this topic. At present there is a lack of regulations or penalties being applied to conventional polluting methods of hydrogen production to make them more expensive and ease the transition to low-carbon hydrogen.

Investigating the incentives and legal barriers for hydrogen system deployment is an on-going task. This paper provides a short, high-level, snapshot. Future research will develop the current analysis to cover a number of additional countries.

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