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Regulating Power-to-Gas in the Energy Union

Ruven Fleming[1]

1. Introduction

By 2020 the European Union shall reduce its greenhouse gas emissions by 20 percent, compared to 1990-levels. Renewable energy shall provide 20 percent of the EU`s total energy consumption and energy efficiency shall be increased by 20 percent.[2] These three goals are commonly referred to as `20/20/20`-targets.[3] Power-to-Gas could assist in this big energy challenge and boost the decarbonisation of the energy sector.

Power-to-Gas is a technology that produces hydrogen, a climate friendly energy carrier, which does not contain a single carbon atom and emits no carbon dioxide at the point of use.[4] This makes hydrogen a climate friendly fuel. In a decarbonized economy it could become the primary energy source for our cars and homes.[5] Because of these and other potential uses Power-to-Gas lately received much attention.[6]

Producing hydrogen in a Power-to Gas plant is not a complicated activity. In the Power-to-Gas process electricity is used to decompose water (H2O) via electrolysis into its elementary components: hydrogen (H2) and oxygen (O2).[7] Oxygen can be released to the atmosphere or used in industrial production processes in the chemical or metallurgical industry. The actual product of Power-to-Gas is hydrogen, which can, in an additional step, be upgraded to Synthetic Natural Gas (SNG) by adding CO2.[8]

Power-to-Gas is a versatile technology that could help with the energy transition in at least two ways. First, it could produce alternative gases like hydrogen or SNG, which could be admixed into our existing gas grid, making it less carbon-intensive. Second, Power-to-Gas could help to store surplus electricity, produced by renewable energy installations at peak times. This re-conversion is called Power-to-Power. This article is concerned with the legal implications of these two Power-to-Gas applications.

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[2] The Presidency Conclusions of the Brussels European Council, 8-9 March 2007 – 7224/07; Hans Vedder et al. `EU Energy Law´ in Martha M Roggenkamp et al. (eds.) `*Energy Law in Europe´* (3rd edition 2016) paragraph 4.10 (hereinafter: Vedder et al.)

[3] Vedder et al. paragraph 4.10-4.18.

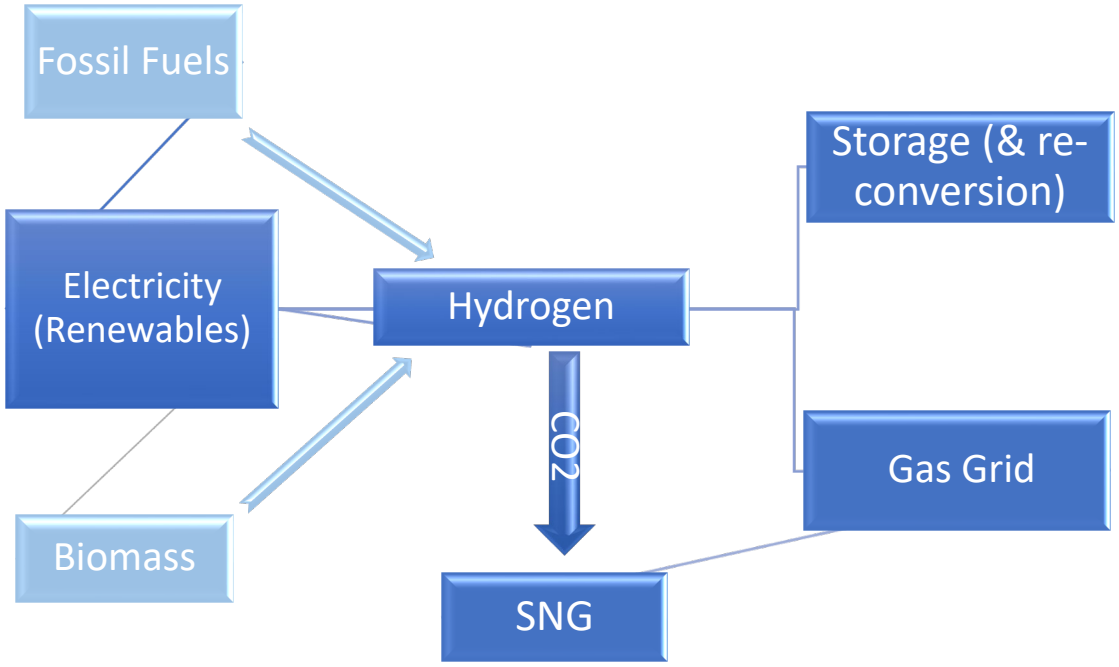
[4] Jeremy Rifkin `*The Hydrogen Economy´* (Tarcher 2002) 8 (hereinafter: Rifkin).

[5] Joseph J Romm `*The Hype about Hydrogen: Fact and Fiction in the Race to Save the Climate´* (2004) 3 (hereinafter: Romm).

[6] Ruven Fleming and Joshua Fershee `The `Hydrogen Economy´ in the US and the EU – Regulating Innovation to Combat Climate Change´ in Donald Zillmann, Lee Godden, LeRoy Paddock, Martha M Roggenkamp (eds.) ` *Innovation in Energy Law and Technology: Dynamic Solutions for Energy Transitions´* (Oxford University Press, 2018) pages 137-153 (hereinafter: Fleming/Fershee); see also Romm 3,4.

[7] Markus Lehner, Robert Tichler, Horst Steinmüller, Markus Koppe `*Power-to-Gas: Technology and Business Models´* (Springer International Publishing, Dordrecht 2014) 7 (hereinafter: Lehner et al.).

[8] Lehner et al. 8. The European Commission is currently researching this additional methanation step for Power-to-Gas in its Horizon 2020 Store & Go project www.storeandgo.info. More on SNG can be found further below in this article.



Source: author`s own work

Current numbers about the `greening´ of the gas sector by alternative gases like hydrogen and SNG are rather sobering. A staggering 96 percent of hydrogen is currently produced from fossil fuels, according to the International Energy Agency.[9] This process generates greenhouse gases in significant quantities.[10] A mere 4 percent of hydrogen is derived from renewable sources via electrolysis.[11] The latter, hydrogen produced from renewable energy sources, is referred to as `green hydrogen´, while the former, hydrogen produced from fossil fuels, is called `grey hydrogen´.[12]

When zooming in on `green´ hydrogen, we can see that it has two main sources. First, biomass-based production and second, electrolysis based on electricity from renewable sources.[13] Biomass is the cheapest of all renewables, but has limited potential for hydrogen, due to the competition between hydrogen, biofuels, and other uses of biomass.[14] According to Ball/Seydel/Wietschel/Stiller, offshore wind via electrolysis/Power-to-Gas could take over in

[9] International Energy Agency `Energy Technology Essentials Hydrogen Production & Distribution´ page 4 table 1 https://www.iea.org/publications/freepublications/publication/essentials5.pdf [accessed 21/June/2018] (hereinafter: IEA Hydrogen). Some sources are even speaking of up to 99 percent hydrogen from fossil fuels, see Hydrogen Council 17.
[10] Romm 3.
[11] Michael Ball, Werner Weindorf and Ulrich Bünger `Hydrogen Production´ in Michael Ball and Martin Wietschel (eds.) `*The Hydrogen Economy: Opportunities and Challenges´* (2009) 279 (hereinafter: Ball/Weindorf/Bünger Hydrogen Production); IEA Hydrogen.
[12] Michael Ball `Why Hydrogen?´ in Michael Ball and Martin Wietschel (eds.) `*The Hydrogen Economy: Opportunities and Challenges´* (2009) 38/39 (hereinafter: Ball); Rifkin 185-192.
[13] Ball/Seydel/Wietschel/Stiller 399. Michael Ball et al. in Michael Ball and Martin Wietschel (eds.) `*The Hydrogen Economy: Opportunities and Challenges´* (2009) 399 (hereinafter: Ball/Seydel/Wietschel/Stiller).
[14] Ball/Seydel/Wietschel/Stiller 418.

the future and play a very important role in hydrogen production after 2020.[15] This, however, will depend on technical advances as well as a clear legal framework for the technology.

The second option, the conversion of (renewable) electricity into hydrogen via Power-to Gas to store energy could help with the integration of renewable energy sources into the electricity system. Renewable energy is produced when the sun is shining and the wind is blowing, but production plummets on cloudy and windless days. This intermittent production pattern could be eased with the help of electricity storage[16], inter alia, via Power-to-Gas.

Power-to-Gas could allow for the conversion of surplus electricity from renewables (producing on sunny and windy days) into hydrogen, which could then be stored and re-converted into electricity (via the fuel cell technology), when needed.[17] This last option is called Power-to-Power. The efforts to accelerate the development of Power-to-Gas in the EU are based on these two ideas: easing the intermittent pattern of renewable energy production and decarbonizing the gas grids.[18]

This article focusses on the energy law framework at EU level and how it applies to the various stages of Power-to-Gas. While there is a substantial number of other legal questions about Power-to-Gas (e.g. the environmental law framework, the planning law framework, the liability law framework, etc.) the current article made the choice to focus on the compatibility of the Power-to-Gas technology with the EU`s energy law framework.[19] It scrutinizes the existing legal framework of the EU and outlines the current and emerging regulatory trends for Power-to-Gas. The article starts by briefly describing the latest proposal of the European Union on energy regulation, outlining possible repercussions for the legal categorization of hydrogen as a form of renewable energy. The article goes on to discuss the two main options of Power-to-Gas use: hydrogen admixture in the natural gas grid and electricity storage via hydrogen. It highlights that the successful introduction of the Power-to-Gas technology depends on an accompanying legal framework that is tailored to the respective Power-to-Gas and or Power-to-Power applications.

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[15] Ball/Seydel/Wietschel/Stiller 418.

[16] See Matthijs van Leeuwen and Martha Roggenkamp `Regulating Electricity Storage in the European Union: How to Balance Technical and Legal Innovation´ in Donald Zillmann, Lee Godden, LeRoy Paddock, Martha M Roggenkamp (eds.) ` *Innovation in Energy Law and Technology: Dynamic Solutions for Energy Transitions´* (Oxford University Press, 2018) pages 159-161.

[17] Rifkin 9.

[18] Fleming/Fershee 139; Kreeft EU at 10; Daisy G Tempelman `Harmonizing Gas Quality: Obstacles and Challenges in an Internal Market´ in Martha M Roggenkamp and Hendrik Bjornebye (eds) *`European Energy Law Report X´* (Intersentia, Cambridge 2014) 88 - 90 (hereinafter: Tempelman 2014).

[19] Other EU law areas and their application to Power-to-Gas have been discussed in Gijs Kreeft `European Legislative and Regulatory Framework on Power-to-Gas Deliverable 7.2´ STORE & GO project, 2017, available at: https://www.storeandgo.info/fileadmin/downloads/20171030_STOREandGO_D7.2_RUG_submitted.pdf [accessed 20/June/2018] (hereinafter: Kreeft EU). The same author also provided an overview of Power-to-Gas specific legislation in selected EU Member States, see: Gijs Kreeft ` Legislative and Regulatory Framework for Power-to-Gas in Germany, Italy and Switzerland Deliverable 7.3´ STORE & GO project 2017, available at: https://www.storeandgo.info/fileadmin/downloads/publications/Kreeft__G.J.__2018__-_Legislative_and_Regulatory_Framework_for_Power-to-Gas_in_Italy__Germany_and_Switzerland.pdf [accessed 06/September/2018] (hereinafter: Kreeft Member States).

2. Energy Law Background: The `Clean Energy for All Europeans´ - package

The applicable energy law framework for Power-to-Gas at the EU level is currently in transition. The European Commission proposed a new legal framework for the European energy system with the aim to take technical developments like Power-to-Gas better into account. By the end of 2016 the EU Commission launched a legislative package called `Clean Energy for All Europeans´.[20] The package consists of a number of proposals,[21] but at its heart are two recast directives, the recast Renewables Directive[22] and the recast Electricity Directive.[23] The recast Renewables Directive and the recast Electricity Directive are relevant for the admixture of hydrogen into the gas grid and/or the storage of electricity via hydrogen and will be discussed in turn. They are contrasted with the existing regulations of a third Directive, the Gas Directive,[24] the revision of which is not part of the new package.[25]

3. Renewable Energy Laws and Hydrogen

It would be desirable for the production of hydrogen from renewable electricity via Power-to-Gas, if the hydrogen resulting from the process could be categorized as renewable energy under the Renewable Energy Directive (hereinafter: RED). The RED includes a number of favourable conditions and privileges for renewable energy, compared to conventional energy, such as guaranteed / priority access to the grids.[26]

Article 2 (a) of the existing RED defines energy from renewable sources as `*energy from non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.´* Since `green´ hydrogen is derived from wind, solar, hydropower, biomass or as biogas, it is falling under that definition. Vice versa, `grey´ hydrogen is derived from fossil fuels and is falling outside of this definition.

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[20] European Commission `Clean Energy for All Europeans – unlocking Europe's growth potential´ http://europa.eu/rapid/press-release_IP-16-4009_en.htm.

[21] European Commission `Commission proposes new rules for consumer centred clean energy transition´ https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition.

[22] European Commission `Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast) COM(2016) 767 final/2 (hereinafter: proposed recast RED).

[23] European Commission `Proposal for a Directive of the European Parliament and of the Council on common rules for the internal market in electricity (recast) COM(2016) 864 final/2 (hereinafter: proposed recast Electricity Directive). Moreover, there are proposals for Directives and Regulations dealing with energy efficiency, but they are not discussed in this article, as they are not directly relevant to Power-to-Gas.

[24] Council Directive (EC) 2009/73 of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC [2009] OJ L 211/94.

[25] However, the Gas Directive is also currently being revised under the umbrella of another legislative initiative, aiming to extend the scope of the EU energy law regime to offshore pipelines coming into the EU (`Nord Stream 2`), see: European Commission `Proposal for a Directive of the European Parliament and of the Council amending Directive 2009/73/EC concerning common rules for the internal market in natural gas 8/November/2017 COM(2017) 660 final available at: https://ec.europa.eu/energy/sites/ener/files/documents/act_gas_dir_adopted.pdf [accessed 12/September/2018].

[26] More on that can be found at Hans Vedder, Anita Ronne, Martha Roggenkamp and Inigo del Guayo `EU Energy Law´ in Martha M Roggenkamp et al. (eds.) `*Energy Law in Europe´* 3rd edition (Oxford University Press, Oxford 2016) paragraph 4.406 (hereinafter: Vedder et al EU Energy Law).

The indirect inclusion of `green´ hydrogen[27] into the scope of the RED via the use of renewable electricity is now turned into a direct recognition under the proposed new recast Renewables Directive:[28] recital 47 notes that the Directive also applies to `(…) *other renewable gases such as hydrogen.´*[29]

Moreover, recital 47 together with article 19 (in particular (1) and (7)), proposed recast RED, extends a major tool of the RED to hydrogen: guarantees of origin shall now be issued for renewable gases, including `green´ hydrogen.[30] According to article 15 of the existing RED each Member State must be able to guarantee the origin of electricity (in the newly proposed recast RED this term is altered to `energy´ to clarify that renewable gases are included). Guarantees of origin have the sole function to prove to a final customer that a given share of energy was produced from renewable sources.[31] However, (seemingly contradictory) a guarantee of origin can be transferred independently of the energy to which it relates, from one holder to the other – regardless of the energy to which it refers.[32] The underlying rationale is to use guarantees of origin as evidence of `green supply´ to receive public support but do not of themselves confer a right to benefit from national support schemes.[33] This system of guarantees of origin was in place for renewable electricity and will now be extended to renewable gases like hydrogen.

4. Hydrogen and the Gas Grid

Although the proposed recast Renewable Directive clarifies that `green´ hydrogen has to be considered as renewable energy, it does not provide a legal framework for the technical applications of hydrogen. As a reminder: the output of Power-to-Gas installations can either be hydrogen or Synthetic Natural Gas (SNG). Mainly two potential uses for Power-to-Gas and the resulting hydrogen or SNG exist: `hydrogen and grids´ and `electricity storage via hydrogen´.[34]

Regarding the first option, hydrogen has been used in gas grids (as part of so called town gas) for more than a century now,[35] while storage of hydrogen in large scale gas storage facilities is a relatively new technical development. Despite the century-old usage of hydrogen in gas grids, expertise on this substantially diminished when town gas was replaced by natural gas in all major industrialized countries.[36]

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[27] A further example for this is article 5 (1) second sentence RED.
[28] European Commission `Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast)´ COM(2016) 767 final (hereinafter: Commission RED proposal).
[29] This reference includes only `green´ and not to `grey´ hydrogen, see European Parliament `Briefing EU Legislation in Progress Promoting renewable energy sources in the EU after 2020´ page 7 http://www.europarl.europa.eu/RegData/etudes/BRIE/2017/599278/EPRS_BRI(2017)599278_EN.pdf.
[30] Article 19 (7) (b) (ii) in conjunction with recital 47 proposed recast RED. To achieve this an amendment of article 19 (1) RED is proposed, according to which the guarantees of origin shall not (as hitherto) only guarantee the origin of electricity from renewable sources, but of `energy´ from renewable sources, see Commission RED proposal COM(2016) 767 final p. 82.
[31] Recital 52 and article 2 (j) RES Directive.
[32] Vedder et al EU Energy Law paragraph 4.400.
[33] Recital 56 RED and Vedder et al. EU Energy Law paragraph 4.401.
[34] IEA Hydrogen 2-4; European Commission `Energy Storage – The Role of Electricity´ SWD(2017) 61 final at 21/22 (hereinafter: SWD Energy Storage).
[35] Reinhold Bauer `A Historical Overview´ in Michael Bargende and Richard van Basshuysen (eds.) `*Natural Gas and Renewable Methane for Powertrains´* (Springer International Publishing, Cham 2016) 28 (hereinafter: Bauer).
[36] Ibid.

Dedicated hydrogen grids still exist today, but they are very regional in nature.[37] It is expensive to build such dedicated grids and those that do exist are mainly used to supply refineries.[38] Due to the huge costs involved in developing a dedicated hydrogen pipeline system,[39] the realistic option for the foreseeable future is feeding hydrogen into the existing natural gas grid. This can be done in two ways: first, by admixing hydrogen to the natural gas stream and second by upgrading hydrogen to natural gas quality (synthetic natural gas), before feeding it into the grid.

4.1 Hydrogen Admixture

The first option, admixture of hydrogen to the gas grid includes a number of challenges. European and national legislation on gas transmission, distribution and supply impacts upon the admixture of hydrogen. The same is true for European rules on end-appliances that are using gaseous fuels, like home-cookers and heating appliances.

Concerning transport, the European law framework for gas is dominated by the Gas Directive as well as an accompanying Regulation.[40] These legislative instruments set out a comprehensive regime for the liberalisation of the European gas market. Their objective is the setting of fair, non-discriminatory rules for the access conditions to the natural gas transmission and distribution networks, storage and LNG facilities.[41] The implications of the Gas Directive and Regulation on the admixture of hydrogen into the gas grids is discussed in D.1.1.

Once the gas has been transported via the grid it reaches the end-user. There are European specifications for end-appliances burning gaseous fuels, which are dominated by certain standards issued by the European Committee for Standardization (CEN) and Regulation 2016/426.[42] They will be discussed in section D.1.2, after the discussion of the regulatory framework for gas transportation and hydrogen admixture.

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[37] Michael Ball, Werner Weindorf and Ulrich Bünger `Hydrogen Distribution´ in Michael Ball and Martin Wietschel (eds.) `*The Hydrogen Economy: Opportunities and Challenges´* (2009) 323 (hereinafter: Ball/Weindorf/Bünger Hydrogen Distribution) identified 16000 km of existing hydrogen pipelines in the world, mainly centering in 5 areas: Belgium, the Netherlands, France, the Ruhr area of Germany and along the Gulf coast in the United States.

[38] Here hydrogen is used for hydrocracking and other applications with the aim of reformulating oil, see Timo Eickelkamp and Ruprecht Brandis `Potenzial und Regelungsbedarf für Power-to-Gas in Raffinerien´ (2017) Volume 67 Issue 1/2 Energiewirtschaftliche Tagesfragen 2/3; Ball/Weindorf/Bünger Hydrogen Production 279.

[39] The International Energy Agency estimates that building such a system would cost several hundred billion US Dollar, see IEA Hydrogen 3.

[40] Regulation (EC) No 715/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the natural gas transmission networks and repealing Regulation (EC) No 1775/2005 [2009] OJ L 211/36 (hereinafter: Regulation 715/2009).

[41] Article 1 (b) in conjunction with preamble 37 of Regulation 715/2009.

[42] Regulation (EU) 2016/426 of the European Parliament and of the Council of 9 March 2016 on appliances burning gaseous fuels and repealing Directive 2009/142/EC [2016] OJ L 81/99 (hereinafter: Regulation 2016/426).

4.1.1 Admixture and the Gas Transport Network

The first important question in relation to gas grids and Power–to-Gas is whether or not hydrogen qualifies as gas under the Gas Directive and the Regulation. The applicability of the existing European regime for gas transport on hydrogen depends on the answer to this question.

Article 1 (2) Gas Directive determines:

> *`The rules established by this Directive for natural gas, including LNG, shall also apply in a non-discriminatory way to biogas and gas from biomass or other types of gas in so far as such gases can technically and safely be injected into, and transported through, the natural gas system.´*

This definition could apply to Power-to-Gas. Judging by its chemical composition as well as the common usage of the term, hydrogen is likely to qualify as *`other type of gas´*. The main question here is if it is technically safe to inject the hydrogen that is stemming from Power-to-Gas plants into the natural gas system and to transport it.

The European Commission and many EU Member States say yes, but only in very limited amounts.[43] The European Commission noted in a staff working document of 1st February 2017 that

> *`Hydrogen can be blended in the natural gas infrastructure up to a certain percentage (between 5-20 percent by volume, as demonstrated by the EC research project NaturalHy) (...) the relevant regulations on gas quality and limits of hydrogen at EU level could define safe levels of hydrogen in the natural gas infrastructure and enable the transfer of the low-carbon value of variable renewable energy sources between the electricity networks and the gas networks.´*[44]

The EU, however, did not yet define what a safe level of hydrogen admixture is. In July 2015 and December 2016, respectively, the European Committee for Standardization issued Norms EN 16723-1[45] and EN 16726.[46] Although these standards are creating a Europe-wide standard for gas quality in the transmission and distribution systems, they exclude the question of hydrogen-admixture from their scope. The reason being that *`for hydrogen, at present it is not possible to specify a limiting value which would generally be valid for all parts of the European gas infrastructure´.*[47] On a different note, however, an Annex E to the standard then explains that ` *The results of the GERG study "Admissible Hydrogen Concentrations in Natural Gas*

[43] For more information on this see Daisy G Templemann `Harmonizing Gas Quality: Obstacles and Challenges in an Internal Market´ 85-112 in Martha Roggenkamp and Hendrik Bjornebye *`European Energy Law Report X´* (2014).
[44] Section 4.2.5 SWD Energy Storage.
[45] Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network – Part 1: Specifications for biomethane for injection in the natural gas network, available at: https://standards.globalspec.com/std/10054866/cen-en-16723-1 [accessed 7/Jne/2018]. However, this standard only addresses natural gas and biomethane.
[46] Gas infrastructure – Quality of gas –Group H available at: http://portailgroupe.afnor.fr/public_espacenormalisation/BNG234/FprEN16726%20(E).pdf [accessed 7/June/2018].
[47] Standard EN 16726:2015 at page 5 and Annex E page 40.

Systems" show that an admixture of up to 10 % by volume of hydrogen to natural gas is possible in some parts of the natural gas system´.[48]

Even if hydrogen would be included in this Annex, this would not necessarily improve the situation as CEN-norms are not legally binding.[49] They merely constitute recommendations for the Member States, which then decide whether or not to follow them.[50] Attempts in the past to make them legally binding failed.[51]

As far as `green´ hydrogen is concerned, the proposed recast RED could be relevant, as it regulates access conditions to the grid and the operation of the grid.[52] Article 20 (2) proposed recast RED obliges Member States to require Transmission System Operators (TSOs) as well as Distribution System Operators (DSOs) to publish technical rules for network connection, including on gas quality, odoration and pressure requirements. However, the TSOs and DSOs are regulated by the Member States. The ball would be played back to the Member States. In sum, this proposed recast RED does not of itself establish a EU-wide standard for the admixture of `green´ hydrogen, or, indeed, any hydrogen.

The gist of the above is that Member State regulation is paramount for the admixture of hydrogen into the natural gas system. Although many Member States allow for injection of hydrogen into the grid and accept mingling of hydrogen with the natural gas stream, the percentage that is considered `safe´ varies considerably from country to country. Different scientific findings, technical variations and the willingness to experiment and accept minor risks vary among Member States and make it difficult to decide on a fixed percentage of hydrogen admixtures.[53] There are a number of ways to resolve this. The EU could either adopt a unified number or clarify directly in the wording of article 1 (2) Gas Directive whether or not it applies to hydrogen. This could be beneficial for the trade of hydrogen-enriched gas-streams and, ultimately, the creation of the long-promised internal gas market in the EU.[54]

4.1.2 Admixture and End-Appliances

Admixing hydrogen to the natural gas stream can have severe repercussions beyond the transportation system, namely on the end-appliances that are deployed by the final users of gas. Different gas appliances have very different sensitivities for gas quality, depending on whether

[48] Annex E to Standard EN 16726:2015.
[49] Martha Roggenkamp, Jacob Sandholt and Daisy G Tempelman `Innovation in the EU Gas Sector Injection of Biomethane into the Natural Gas System´ in Donald Zillman, Martha Roggenkamp, LeRoy Paddock and Lee Godden (eds.) `*Innovation in Energy Law and Technology Dynamic Solutions for Energy Transitions´* (Oxford University Press, Oxford 2018) 267 (hereinafter: Roggenkamp/Sandhold/Tempelman).
[50] Ibid.
[51] Conclusions of the 29th meeting of the Madrid Forum, 6-7 October2016, at page 2, document called `29th_mf_conclusions_adopted´ available online in a folder with documents concerning the 29th meeting at: https://ec.europa.eu/energy/en/madrid-forum-previous-meetings [accessed 11/June/2018].
[52] Article 20 Commission RED proposal p. 85/86.
[53] In Germany, for example, the standards are set by the *Deutscher Verein des Gas und Wasserfachs (DVGW),* which issued two guideline notes (Arbeitsblätter G 260 and G 262) that consider hydrogen admixture `in single digits´ safe. A more recent study by the DVGW, however, found that up to 10 percent hydrogen admixture can be viewed safe Holger Dörr etal.`Untersuchungen zur Einspeisung von Wasserstoff in ein Erdgasnetz´ (2016) 11 Energie/Wasser-Praxis 50-59 http://www.dvgw-ebi.de/download/ewp_1116_50-59_Kroeger.pdf.
[54] For the development of the EU internal gas market and its insufficiencies see: Vedder et al paragraphs 4.04 – 4.18.

household appliances or industrial applications (for instance gas turbines) are concerned.[55] Gas home appliances (cooking, heating, etc.) have been designed to run on gas that lies within a particular bandwidth of qualities, which differ from Member State to Member State.[56]

This phenomenon is explained best by looking at the difference between low calorific gas (L-Gas) and high calorific gas (H-Gas). While Europe`s largest domestic source of gas, the Groningen gas field in the Netherlands, is producing gas of L-Gas quality, most gas imports from Russia, Norway and Algeria (to name the main suppliers) consist of H-Gas.[57] If a country or a region within a country, wishes to switch from L-Gas to H-Gas, home-appliances must be retrofitted or replaced, which is a costly exercise.[58]

The CEN publishes recommendations for voluntarily harmonised EU-wide standards for household appliances, but as discussed above, such CEN standards are not legally binding. The only legally binding obligation in that respect is, according to article 4 (1) of Regulation 2016/426, the obligation of Member States to exchange information on types of gas and corresponding supply pressures of gaseous fuels used on their territory by October 2017. They must also communicate any changes thereof within six months after the announcement of the envisaged changes.[59]

There is a Europe-wide Regulation on appliances burning gaseous fuels (hereinafter. Regulation 2016/426),[60] which established in its article 15 (1) in conjunction with Annex I that such appliances must receive an EU declaration of conformity. This declaration certifies that the appliance is meeting essential requirements.[61] However, analysis of the requirements shows that they are addressing the construction and safe deployment of the end-use appliance as such and are not dealing with the chemical composition of the gas on which they are running. Thus, the EU rules on end-use appliances that are burning gaseous fuels do not prescribe a Europe-wide unified gas composition. If the EU would prescribe such a unified standard for gas composition it needs to give very precise numbers on certain features. Those would, inter alia, be the allowed energy content in a cubic metre of gas, the allowable increase or decrease of

[55] Gas-turbines, for instance, are very sensitive to any change in the composition of the gas, see GL Noble & Pöyry Managment Consulting `Study on Interoperability – Gas Quality Harmonization – Cost Benefit Analysis Final Report´ (GL Industrial Services, 2012) at 2 available at: https://ec.europa.eu/energy/sites/ener/files/documents/2012_gas_quality_harmonisation_cost_benefit_analysis_.pdf [accessed 11/June/2018].

[56] Tempelman 2014 at 88 – 90.

[57] Tempelman 2014 at 88.

[58] The Regulator of the biggest EU Member State Germany (*Bundesnetzagent*ur), for instance, announced intentions to phase out L-Gas in the whole of Germany by 2029, see http://www.bundesnetzagentur.de/cln_1421/DE/Sachgebiete/ElektrizitaetundGas/Verbraucher/NetzanschlussUndMessung/UmstellungGasbeschaffenheit/UmstellungGasqualitaet-node.html [accessed 11/June/2018]. The costs for this have been estimated to lie around 1.7 billion Euros, see https://www.ispex.de/marktraumumstellung-gas-kosten-tragen-die-endkunden/ [accessed 11/June/2018].

[59] Article 4 (1) Sentence 2 Regulation 2016/426.

[60] Regulation (EU) 2016/426 of the European Parliament and of the Council of 9 March 2016 on appliances burning gaseous fuels and repealing Directive 2009/142/EC [2016] OJ L 81/99 (hereinafter: Regulation 2016/426).

[61] Annex I comprises of a long list of requirements, amongst which are such general obligations like the need for all appliances tob e designed and constructed to operate safely and present no danger to persons, domestic animals or property, when normally used, see article 1.1 Annex I Regulation 2016/426, but also very specific ones.

temperature of the flame, how possible embrittlement of pipes and nozzles[62] will be dealt with and finally should include rules that diminish the risk of explosions.[63]

4.2 Power-to-SNG

An alternative to circumvent the legal uncertainties about the applicability of the Gas Directive would be to upgrade hydrogen by methanation to bring it to natural gas quality. Instead of feeding hydrogen into the natural gas grid, hydrogen can be upgraded to synthetic natural gas (SNG) via methanation.[64] The chemical process is rather straightforward: hydrogen and carbon dioxide (CO2) synthesize to methane, either by a chemically or biologically catalysed reaction.[65]

The main advantage of methane as end-product is its unlimited usability in the gas infrastructure.[66] The physical and chemical properties of SNG and natural gas are largely the same.[67] The main disadvantage of SNG is that its energy efficiency is lowered through the additional conversion step.[68]

The source of the carbon dioxide that is used for methanation can be important, depending on the legislatory level. In a recent project (STORE & GO[69]) three different sources of carbon dioxide (fossil fuels, biogenic, ambient air) have been scrutinized for usage in methanation.[70] The project found that applicable legislation at EU level, namely the Renewable Energy Directive, is unbiased towards the source of carbon used for methanation.[71]

This, however, does not mean that Member States might not have their own legislation on the sources of carbon dioxide for methanation. Kreeft has shown that three European states (Italy Germany and Switzerland, although the latter is not a member of the political union EU) have very different regulations in place. Under these regulations the source of carbon is relevant for the resulting SNG to become eligible for financial support schemes.[72] Italy adopted a support scheme for biomethane as transportation fuel, where SNG is only eligible if the carbon dioxide used to produce SNG is of biogenic nature.[73] In Switzerland, a law on SNG vehicles only provides support if the SNG has been created via carbon dioxide stemming from ambient air capture.[74] In Germany, the carbon dioxide must be produced `predominantly` from renewable sources, if the resulting SNG shall be eligible for financial support.[75]

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[62] Klaus Altfeld and Dave Pinchbeck `Admissible hydrogen concentrations in natural gas systems´ Issue 3 (2013) gas for energy page 5 available at: http://www.gerg.eu/public/uploads/files/publications/GERGpapers/SD_gfe_03_13_Report_Altfeld-Pinchbeck.pdf [accessed 6/September/2018].
[63] For more on that see Kreeft EU page 41 with further references.
[64] The European Commission is currently researching this additional methanation step for Power-to-Gas in its Horizon 2020 Store & Go project www.storeandgo.info.
[65] Lehner et al. 8.
[66] Ibid.
[67] Lehner et al. 9.
[68] Ibid.
[69] More can be found at the project`s webpage available at www.storeandgo.info [accessed 6 /September/2018].
[70] Kreeft EU page 14.
[71] Kreeft EU pages 8 and for more details 49-51.
[72] Kreeft Member States page 9 and 75-89.
[73] Ibid.
[74] Ibid.
[75] Kreeft Member States pages 51/52; `predominantly´ meaning to at least 80 percent.

The results of section D on the gas grid can be summed up as follows: it is more likely than not that the Gas Directive applies to the transportation of hydrogen via the gas grid, but even if a different stance would be taken, at least for SNG injection into the grid the Gas Directive applies. The result is that hydrogen in certain amounts and SNG in general would have to be treated like any other gas in the system under the Gas Directive.

Regarding the usage of gas in end-appliances, the current EU energy law framework does not specify the quality or composition of the gases that they are running on. If a future regulation should be drawn up in this area it should feature clear and precise rules on a number of issues that have been briefly touched upon above. The technical safety and design of pipelines that are bringing the mingled natural gas/hydrogen stream to households and the safety of the end-appliances would both have to be taken care of in such a regulation.

5. The Storage of Hydrogen

There is also a different, second future use for hydrogen produced via Power-to-Gas. It can be used to store electricity.[76] The available alternatives to electricity storage to facilitate the balancing of electricity grids are demand management and the ever-increasing extension of the electricity grid. However, these alternatives have their limits, so storage of renewable energy is crucial as an additional possibility to create a portfolio of grid balancing solutions, even more so if the share of intermittent renewable energy in power production is increasing in the future.[77]

Excess electricity of off-peak renewable energy generation can be used to produce hydrogen via Power-to-Gas. The hydrogen is stored and released at times of high electricity demand, but low output of electricity from renewables. It is then re-converted to electricity via fuel cells.

Hydrogen is a good overall solution for long-term, carbon-free seasonal storage, since competing technologies like batteries, super-capacitors and compressed air lack either the power capacity or the storage timespan needed to address seasonal imbalances.[78] Hydrogen can be potentially stored underground in salt domes, caverns and even in depleted oil and gas fields.[79]

Despite substantial technical experience with hydrogen storage, its legal categorisation is not yet sufficiently clear. There are essentially two possibilities: hydrogen storage facilities could be governed by the rules of the Gas Directive or, given that the hydrogen is stored for re-

[76] Maximillian Fichtner 'Hydrogen Storage' in Michael Ball and Martin Wietschel (eds*) The Hydrogen Economy: Opportunities and Challenges* (Cambridge University Press 2009) 309 (hereinafter: Fichtner).
[77] Lehner et al. 9.
[78] The Hydrogen Council `How hydrogen empowers the energy transition´ (January 2017) 17 respectively available at: http://hydrogeneurope.eu/wp-content/uploads/2017/01/20170109-HYDROGEN-COUNCIL-Vision-document-FINAL-HR.pdf [accessed 3/May/2017] at 6 (hereinafter: Hydrogen Council).
[79] Hydrogen Council 17; Fichtner 317/318.

conversion to electricity, it could fall into the scope of the Electricity Directive[80] and its proposed recast[81] under the `Clean energy for All Europeans´-package.

5.1 Hydrogen Storage and the Gas Directive

Gas storages are defined in article 2 (9) Gas Directive as *`facility used for the stocking of natural gas and owned and/or operated by a natural gas undertaking (...).´* This could mean that only natural gas storage facilities are included in the scope of the Gas Directive. Since hydrogen is not natural gas, it would fall outside of this scope.

Despite this, seemingly clear, wording hydrogen storage could actually be covered by the Gas Directive. Article 1 (2) Gas Directive notes that rules in the Gas Directive for natural gas shall also apply to other types of gas. As we concluded earlier, hydrogen in principle is *`other type of gas.´*

But there is a catch. The rules of the Gas Directive only apply to other types of gas *`in so far as such gases can technically and safely be injected into, and transported through, the natural gas system.´*[82] For our purposes we do not want to inject hydrogen into the gas grid, but in a storage facility, so do the rules still apply?

The last word in this sentence holds the key to the solution: *`system´*. Article 1 (2) Gas Directive is not referring to the technical and safe injection of other gases into the natural gas *grid*, but into the `natural gas *system´*. *`System´* in itself is defined by article 2 (13) Gas Directive as meaning *`any transmission networks, distribution networks, LNG facilities and/or storage facilities (...).´* Storage is thus, part of the *`system´*. Technically safe injection and storage of hydrogen in caverns has been done for many years in the EU.[83] As a consequence, the Gas Directive applies to hydrogen storage facilities.

There are two most important practical repercussion of this analysis. The first one is that the unbundling rules for gas storages under the G-Directive apply to hydrogen storages. According to article 15 G-Directive, the operator of a gas storage facility has to be unbundled, which means storage system operators which are part of vertically integrated undertakings shall be independent at least in terms of their legal form, organisation and decision making from other activities not relating to storage.[84]

The second repercussion is that third party access to hydrogen storage facilities would have to be granted, according to article 33 (1) G-Directive. There are two different systems for guaranteeing third party access that Member States can choose from, negotiated (article 33 (3) G-Directive) and regulated (article 33 (4) G-Directive) third party access. The difference is that

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[80] Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC [2009] OJ L 211/55 (hereinafter: E-Directive).

[81] European Commission `Proposal for a Directive of the European Parliament and of the Council on common rules for the internal market in electricity (recast)´ COM(2016) 864 final/2 (hereinafter: Commission recast Electricity Directive proposal).

[82] Article 1 (2) Gas Directive.

[83] Fichtner 318; Hydrogen Council 6; John Burdon Sanderson Haldane `Daedalus or Science and the Future A paper read to the Heretics, Cambridge, on February 4th, 1923´ reproduced at: http://bactra.org/Daedalus.html#note4; a reproduction of this section is also available at Rifkin 181.

[84] More on the EU-wide process of unbundling that turned the European energy market upside down can be found at Vedder et al. paragraphs 4.192 – 4.206.

under negotiated access, the owner of a storage facility is obliged to negotiate access with the applicant (i.e. conditions and tariffs), while the applicant has the right to access under published conditions and tariffs under a regulated regime.

5.2 Hydrogen Storage and the proposed recast Electricity Directive

At the same time, however, the European Union is working on a definition of electricity storage and, depending on the exact wording, this could apply to Power-to-Gas facilities simultaneously. The starting point for this issue is the currently existing Electricity Directive of 2009. It simply does not include any provisions on electricity storage. However, with the new `Clean Energy for All Europeans´-package, the European Institutions (Commission[85], Parliament[86] and Council[87]) are all three proposing to include a provision on electricity storage into the proposed recast Electricity Directive.[88]

The proposed definitions of all three institutions differ slightly, but all three are covering Power-to-Gas as a storage technology. Article 2 (47) of the initial Commission proposal defines energy storage in the electricity system as *`deferring an amount of the electricity that was generated to the moment of use, either as final energy or converted into another energy carrier.´*[89]

This article 2 (47) has been elaborated upon by a staff working document (SWD) of the European Commission,[90] which explains that *`storage within the electricity system covers all power-to-power solutions, including batteries, pumped hydro and compressed air energy storage. It also covers power-to-hydrogen when the produced hydrogen is used for re-electrification (...).´*[91] The Commission, thus, proposes storage legislation that applies to electricity, but can be achieved via other energy carriers like hydrogen.

The other two proposed definitions are a bit longer and more explicit in wording. In both the Parliament`s and the Council`s definitions the word `reconversion` features, which is absent from the proposal of the Commission for an energy storage article. In that sense they would be more explicit for Power-to-Gas as a storage option. But since the SWD clarified explicitly that the Commission also did not intend to exclude Power-to-Gas as a storage option from the scope of the proposed recast Electricity Directive, it would also be covered, albeit more implicitly.

Thus, regardless which of the three definitions makes it into the final text of the recast Electricity Directive at the end of the legislative procedure, Power-to-Gas as a storage option will feature. This, however, means that hydrogen storage would be governed by both the gas

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[85] Commission recast Electricity Directive proposal.
[86] European Parliament Committee on Industry, Research and Energy `Report on the proposal for a directive of the European Parliament and of the Council on common rules for the internal market in electricity (recast) (COM(2016)0864 – C8-0495/2016 – 2016/0380(COD)) of 27/February/2018 available at: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-%2F%2FEP%2F%2FNONSGML%2BREPORT%2BA8-2018-0044%2B0%2BDOC%2BPDF%2BV0%2F%2FEN [accessed 11/June/2018].
[87] Council of the European Union `Interinstitutional File: 2016/0380 (COD) Brussels, 20 December 2017 15886/17´ available at: http://data.consilium.europa.eu/doc/document/ST-15886-2017-INIT/en/pdf [accessed 11/June/2018].
[88] See the respective documents and their elaborations on article 2 (47).
[89] Article 2 (47) Commission recast Electricity Directive proposal.
[90] SWD Energy Storage.
[91] SWD Energy Storage section 4.1.

and the (new recast) Electricity Directive simultaneously. As such this is not necessarily a problem if the remaining provisions of the new recast Electricity Directive will be designed in a way that clarifies the interplay and avoids conflict with provisions of the existing Gas Directive. Given the fact that gas and electricity regulation at EU level was designed hand in hand in the past and took similar directions[92] it can be expected that the EU carries on with that approach also for new legislation – but the devil is in the detail.

5.3 Ownership of Hydrogen Storage Facilities

The next question is who is allowed to own the required hydrogen storage facilities. There are four different options: electricity generators, electricity Transmission System Operators (TSOs) / Distribution System Operators (DSOs),[93] independent organisations/persons or final electricity consumers could potentially own Power-to-Gas storage facilities.

To start with the last option first: consumers can practically be discounted from this discussion. Only real big electricity consumers could run their own storage facilities, but would have no incentive to do so, since European consumers are usually supplied with a steady stream of electricity, generated further up in the energy chain.

At the other end, the top of the energy supply chain, there is currently a real interest by renewable energy generation companies in Power-to-Gas.[94] Their aim is to generate a steady stream of electricity before it is fed into the grid.[95] Running an energy storage facility as an energy producer can, however, conflict with rules on the liberalisation of the European energy market. Under the Gas Directive, for example, producers may be allowed to **own** a gas storage facility, [96] but Member States can appoint or oblige them to appoint storage system operators that are **running** those storage facilities.[97] A prohibition for producers / generators to run storage facilities, similar to the one in the Gas Directive, does not feature in the proposed recast Electricity Directive. In the absence of an explicit prohibition it has to be assumed that electricity generators could run those facilities.

The key-point is the categorisation of hydrogen storage for electricity generation purposes. Is it storage of gas (then the Gas Directive applies) or storage of electricity in the form of gas (which is possible under the new recast Electricity Directive)? The European legislator should consider this bit of the proposed recast Electricity Directive carefully and revisit the proposal for clarification.

Further down in the supply chain, TSOs and/or DSOs could also develop an interest in running hydrogen storage facilities. That, however, can only be electricity TSOs/DSOs and not gas TSOs/DSOs for the purpose of the proposed recast Electricity Directive, which is only dealing with electricity. As a starting point it has to be understood that energy storage has been designed

[92] For a history of the three energy packages that the EU issued since 1996/1998 see: Vedder et al. paragraph 4.08.
[93] The function of TSOs and DSOs is explained in Vedder et al. paragraphs 4.224-4.245.
[94] A good example for Power-to-Gas experiments is the windturbine- and electricity producer Enercon, see: Enercon Storage Technology `First pilot projects for energy storage realised´ (2015) Issue 3 Windblatt 10-15 http://www.enercon.de/fileadmin/Redakteur/Medien-Portal/windblatt/pdf/en/WB_032015_GB_150dpi.pdf.
[95] Ibid.
[96] Article 2 (9) in conjunction with 2 (1) Gas Directive.
[97] Article 12 Gas Directive.

under European energy market rules as a competitive activity, which TSOs/DSOs should stay away from.[98]

In line with this general rule, articles 36 (1) (dealing with DSOs) and 54 (1) (dealing with TSOs) of the proposed recast Electricity Directive state that neither TSOs nor DSOs would be allowed to own, manage or operate[99] energy storage facilities. There can, however, be exceptions to that rule: either if other parties, following an open and transparent tendering procedure, have not expressed their interest to own, develop, manage or operate storage facilities or the facilities are necessary for the distribution system operators to fulfil their obligations.[100]

Finally, there is the option that independent parties are running hydrogen storage facilities. Under the current proposal for a recast Electricity Directive there is nothing to prohibit such independent parties to engage in storage activities and it would also fall in line with the overall rationale of energy market liberalisation in Europe[101] to have different activities assigned to independent parties.

In sum, two different legislative instruments, the Gas Directive and the proposed recast Electricity Directive could apply simultaneously to hydrogen storage. Depending on the actual wording of the recast Electricity Directive, the new-to-built norm on electricity storage could allow certain players in the gas supply chain to engage in new activities. The regulator has to pay attention to this to produce a coherent new law.

6. Conclusion

Hydrogen can be a green energy resource that could help the EU with attaining its 20/20/20 targets. In order to use hydrogen, the industry is facing several technical challenges such as advancing the availability of large-scale Power-to-Gas facilities and suitable hydrogen storages. These technical developments need to be accompanied with legal frameworks/innovations for successful implementation. At the end of the day the use of Power-to-Gas in the development of a `hydrogen economy´ does not only depend on technical innovation, but also on innovative adaptions in law.

The need to generate more renewable energy is one of the main drivers of the interest in Power-to-Gas in Europe. If hydrogen is injected into the gas grid, a re-definition of gas quality standards is needed to create a unified internal gas market. If used for storage of electricity a

[98] European Commission Directorate General Energy `Energy Storage – Proposed policy Principles and Definitions´ (June 2016) https://ec.europa.eu/energy/sites/ener/files/documents/Proposed%20definition%20and%20principles%20for%20energy%20storage.pdf.

[99] In the case of DSOs even `own, develop, manage or operate´, see article 36 (1) proposed recast E-Directive.

[100] Article 36 (2) proposed recast E-Directive provides three complementary conditions in which Member States can allow DSOs to deviate from this general rule: (a) other parties, following an open and transparent tendering procedure, have not expressed their interest to own, develop, manage or operate storage facilities;
(b) such facilities are necessary for the distribution system operators to fulfil their obligations under this Directive for the efficient, reliable and secure operation of the distribution system; and
(c) the regulatory authority has assessed the necessity of such derogation taking into
account the conditions under points (a) and (b) and has granted its approval. Interestingly, the possibilities for deviations that also exist for TSOs (article 54 (2) proposed recast E-Directive) are broadly the same, but are slightly stricter. To give an example on addition to exception (b) the facilities must also not be used to sell electricity to the market, an exception that does not exist in article 36 proposed recast E-Directive.

[101] Vedder et al paragraph 4.203.

new, innovative provision might need to be drafted to fully implement the legislator´s will. The issue of overlap, namely that both the Gas- and the Electricity Directive would govern the storage of hydrogen created by Power-to-Gas needs to be tackled. By reconciling and aligning provisions of the Gas Directive and the proposed recast Electricity Directive, the EU could work towards an increased interlinkage between gas and electricity legislation, possibly creating technology neutral regulation.

It will be crucial to watch closely whether legislators can follow through in creating legal frameworks that support climate-friendly technologies like Power-to-Gas. The ever-increasing technical integration of different energy sources is certainly creating pressure in that direction. The `Clean Energy for All Europeans´-package might be good first step, but it has not even been resolved yet.