European Legislative and Regulatory Framework on Power-to-Gas

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STORE&GO

Innovative large-scale energy storage technologies and Power-to-Gas concepts after optimisation

D7.2

European Legislative and Regulatory Framework on Power-to-Gas

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Table of Contents

List of Abbreviations

ACER	Agency for the Cooperation of Energy Regulators
AIB	Association of Issuing Bodies
BAT	Best Available Technique
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CEN	European Committee for Standardization
CLOE	Levelised costs of producing energy
ECHA	European Chemicals Agency
EFTA	European Free Trade Area
EIA	Environmental Impact Assessment
ENTSO-E	European Network of Transmission System Operators for Electricity
ENTSO-G	European Network of Transmission System Operators for Gas
EU ETS	EU Emission Trading Scheme
EU	European Union
GERG	European Gas Research Group
ISO	Independent System Operator
ITO	Independent Transmission System Operator
LNG	Liquefied natural gas
PPORD	Product and process orientated research and development
PtG	Power-to-gas
RES	Renewable energy source
SNG	Substitute/synthetic natural gas
TWh	Terawatt hours

Executive Summary

The STORE&GO project is a Horizon 2020 project which demonstrates three innovative power-to-gas concepts at demonstration sites in Germany (Falkenhagen), Switzerland (Solothurn), and Italy (Troia).[1] The overall objective of the project is to demonstrate how power-to-gas can provide synergies between electricity and gas as energy carriers for the transportation, storage, and end-use of renewable energy.

Object and Scope of this Deliverable

This Deliverable 7.2 is part of the work within the STORE&GO project and has as its objective to identify legal and regulatory challenges at the level of the European Union (EU) for the deployment of power-to-gas. Together with Deliverable 7.3, which will assess national legislation applicable to power-to-gas in the countries where the STORE&GO pilot plants are sited (Germany, Switzerland, and Italy), this Deliverable is part of Task 7.3 of the STORE&GO project, which focus is on legal and regulatory barriers. Together, Deliverable 7.2 and 7.3 will provide input for the STORE&GO roadmap, which will be presented near the end of the project in 2020.

Overview of the Content and Key Findings

Power-to-gas relates to many dimensions of European energy and environmental law. In the first place, the cross-sectoral nature of power-to-gas links it to both electricity and gas networks and markets, and thus correlated EU legislation included under the 2009 Third Energy Package and proposed Clean Energy for all Europeans Package of 2016. Furthermore, the capacity of power-to-gas to store large quantities of renewable energy requires to reflect on the proposed legal framework on energy storage which has proposed under Clean Energy for all Europeans Package. As power-to-gas cannot only be considered to be an energy storage technology, but also an energy conversion/production activity which produces a gas from electricity generated from renewable sources, more legal issues are raised under the Renewable Energy Directive, such as the question whether the choice of carbon source for the methanation process is conditioned in anyway. Finally, EU environmental law and the law applicable to the safe production and supply of chemicals are discussed in order to assess which requirements flow therefrom for developers/operators of power-to-gas installations. Below, the most important key findings of this Deliverable are listed. More key findings are provided at the beginning each Chapter.

1. **Necessity to align definitions and ownership regimes for power-to-gas under EU electricity and gas legislation**

Power-to-gas is likely to be covered under the proposed definition and ownership regime for energy storage under the Recast Electricity Directive, also when the stored energy is not reconverted into electricity but discharged as a gas. However, the conversion of electricity to a gas, which can also be considered a gas production activity, and the subsequent storage thereof, is also regulated under the 2009 Gas Directive. Ambiguities remain on how these definitions and ownership regimes align. In the first place, it needs to be clarified to what extent power-to-gas is both an energy storage and gas production activity. Second, it needs to be clarified how the conditional ownership and operation of a power-to-gas energy storage facility by a network system operator under the Recast Electricity Directive aligns with the prohibition for such operators to perform production activities under the 2009 Gas Directive. Third, it needs to be clarified to what extent gas storage system operators are allowed to operate a power-to-gas energy storage facility when this could also be considered a gas production activity. It would thus be required that the EU legislator explicitly prescribes to what extent the proposed legal framework on energy storage

[1] *See* STORE&GO project website: www.storeandgo.info.

applicable to power-to-gas takes precedence over similar rules under the 2009 Gas Directive. In the future, a single Directive covering both the internal market for gas and electricity may reflect the increasing sectoral integration in the energy sector.

2. Need for continued efforts to harmonise gas quality standards

Gas quality harmonisation efforts under the umbrella of the European Committee for Standardisation have not resulted in consensus on a common Wobbe Index or hydrogen limit. In absence of such harmonised standards, the heterogeneous parameters of the Member States remain in place. When such parameters are (too) stringent or differ between two Member States, this may hamper the injection of alternative and more sustainable gases to the natural gas system and the cross-border trade therein.

3. Need to clarify the position of substitute natural gas under the Renewable Energy Directive

The three STORE&GO pilot sites all produce a gas by, in a first stage, producing hydrogen from renewable electricity and, in a second stage, synthesising this hydrogen with a carbon source, which can be of a fossil, biogenic, or ambient source. The output gas is commonly known as synthetic, or substitute, natural gas (SNG). Although a 2015 amendment to the Renewable Energy Directive has introduced the term "*renewable liquid and gaseous transport fuels of non-biological origin"* which may cover SNG, this only applies to transport. As SNG can also be used in other sectors such as heating/cooling or electricity production, it should be assessed whether this term should be expanded to cover other sectors as well. Furthermore, although it will be argued in this Deliverable that the Renewable Energy Directive is unbiased towards the carbon source used for methanation, and that the sustainability criteria for biomass do not apply to biogenic carbon sources, legal certainty would require that these matters are explicitly addressed.

4. Need for harmonised rules on network tariffs for energy storage and power-to-gas

An often mentioned financial barrier for energy storage technologies, including power-to-gas, are the network tariffs which need to be paid double as both consumer (of electricity during charging) and producer (during discharging). The recently proposed Recast Electricity Directive allows the European Commission to adopt specific guidelines for network tariff for energy storage. This would allow for a specific tarification regime that recognises the contribution of energy storage and power-to-gas to decarbonisation and security of supply, in the same spirit as the recently adopted tariff regime for gas storage facilities.

5. Need for guidance with regard to financial (dis)incentives for power-to-gas

The guidelines on state aid for environmental protection and energy 2014–2020 provide guidance on the legality of support schemes for renewable energy such a biogas production. However, no attention has (yet) been awarded to power-to-gas or energy storage projects. Similarly, the sections in the guideline on exemptions for energy intensive industry for green surcharges make no explicit reference to such activities. The adoption of specific rules may guide Member States in their design of financial incentives for power-to-gas projects.

6. Need to clarify the position of fossil Carbon Capture and Storage (CCU) under the EU emission trading scheme

Although the STORE&GO sites all use biogenic or ambient carbon for methanation, another possible carbon source is fossil carbon captured at end-point. Clarification is required on the issue whether the capture and transfer of fossil CO_2 for CCU, for example as feedstock for SNG, needs to be covered by allowances under the EU emission trading scheme. More specifically, the question is whether CCU for the production of fuels is covered by the phrase "*permanently stored or avoided"* under the EU emission trading scheme for the post-2020 era.

7. Necessity to develop harmonised rules on guarantees of origin which take account of the need for seasonal storage

A system for guarantees of origin harmonised at the EU level could provide detailed rules on, amongst others, how guarantees of origin for different forms of energy (e.g. electricity and gas) interact when one form of energy is converted into another. Furthermore, looking at the rules on guarantees of origin as proposed under the Recast Renewable Energy Directive, the proposed shortened lifespan of guarantees of origins needs to be reconsidered as this may disincentive the long-term storage of renewable energy.

8. Need to clarify on the applicability of EU environmental legislation

Hydrogen and SNG are chemicals of which the production, including the construction and operation of a power-to-gas plant, is regulated under EU legislation related to the protection of the environment and human health. As, however, the relevant legislative instruments contain no direct reference to power-to-gas, their applicability remains partially open to interpretation. For example, it cannot be determined with certainty whether the obligation to perform an environmental impact assessment flows automatically from its status as Annex I project under the Environmental Impact Assessment, or may be left to the discretion of the Member States as is the case for Annex II projects.

9. Need to consider an exemption for SNG for registration under the REACH Regulation

Producers of SNG have to comply with the registration requirements for chemical substances under the REACH Regulation. However, substances with similar characteristics are exempted from such an obligation. This is for example the case for natural gas and biogas, but also for the substance which are used as a feedstock for SNG: hydrogen and CO_2. It may thus be appropriate to consider a similar exemption for SNG for registration under the REACH Regulation.

10. Need to consider to include energy storage and power-to-gas under the streamlined and simplified administrative procedures under the Recast Renewable Energy Directive

Although the “one stop one shop” requirement for the permitting process of renewable energy projects is a positive development, energy storage and power-to-gas are not explicitly included.

1 Introduction

The European energy system is undergoing drastic changes. Fossil energy sources are replaced by renewable sources, consumers become producers, baseload units become backup, and electrons can become molecules. Underlying all these changes are various technologies which either enable the production of energy from renewable sources, or address the challenges which are associated with the variable output thereof, such as the need to store surpluses of electrical energy. Among these innovative technologies is power-to-gas. In a broad sense, the concept “power-to-gas” encompasses all technologies which, in a first stage, convert (excess) electricity into hydrogen, and optionally, in a second stage, synthesise the hydrogen with carbon dioxide to produce a synthetic gas, also known as substitute natural gas (SNG).[1] As the term “substitute natural gas” suggests, SNG has similar characteristics as natural gas and can, therefore, be transported and stored within the existing natural gas infrastructure. As such, not only can power-to-gas be considered a solution for the large-scale and seasonal storage of electricity, it can simultaneously be considered an innovative and sustainable alternative to natural gas, thereby contributing to the achievement of climate objectives and security of supply by the European Union (EU) and its Member States.

This Deliverable under the scope of the STORE&GO Horizon 2020 project aims to provide an assessment of the European legislative and regulatory framework applicable to power-to-gas. As can already be observed by taking a quick glance over the table of contents, power-to-gas touches upon many different topics of European law. This diversity in topics can primarily be explained by the variety of technological and functional interfaces which power-to-gas shares with both the electricity and the gas sector. Besides these electricity and gas dimensions of power-to-gas, this Deliverable also covers the position of SNG under EU renewable energy legislation, and environmental and safety legislation applicable to power-to-gas installations.

1.1 Objectives and Scope of this Deliverable

1.1.1 Scope of the STORE&GO Project

STORE&GO is a project within the research topic on “Large-Scale Energy Storage” of the EU Horizon 2020 research and innovation programme. This topic addresses the challenges which are associated with high penetrations of intermittent renewable energy and the need to balance supply and demand of energy over longer periods of time through large scale energy storage technologies. Energy storage activities and technologies to which the topic relates are not limited to those which solely focus on the storage of electricity (e.g. batteries or pumped hydro energy storage). Also included are technologies such as power-to-gas and Power-to-Heat which allow for synergies between different energy carriers, energy infrastructures, and end-uses of energy. Irrespective of the technology, the participating projects are expected to contribute to:

- The wider use of storage technologies in the energy system;
- The integration of increasing shares of variable renewable energy, and;
- The deference of expensive grid upgrades which are associated with high shares of intermittent renewable energy.

The STORE&GO project demonstrates three innovative power-to-gas concepts at demonstration sites in Germany (Falkenhagen), Switzerland (Solothurn), and Italy (Troia).[2] The overall objective of the project is to demonstrate how power-to-gas can provide synergies between electricity and gas as energy carriers for the transportation, storage, and end-use of renewable energy. By taking

[2] *See* STORE&GO project website: www.storeandgo.info.

a multi-disciplinary approach, the twenty-seven project partners collaborating within STORE&GO a multidisciplinary approach, the twenty-seven project partners collaborating within STORE&GO aim to overcome technical, economic, social and legal barriers to the deployment of power-to-gas in the future European energy system.

STORE&GO is one of the projects participating in BRIDGE Horizon 2020.[3] BRIDGE is an initiative by the European Commission for the cooperation of 32 projects which are funded under the Horizon 2020 research programme of the European Union. Combined, these projects bring together 379 organisation from 31 countries. The projects participating in BRIDGE share being labelled as so called “Low Carbon Energy Smart-Grid and Energy Storage” projects and are all active in the development of a broad range of innovative smart- and storage technologies. In a collective response to the recently proposed Clean Energy for All Europeans Package by the European Commission (hereafter “Clean Energy Package”), the BRIDGE group has presented an analysis report to the European Commission. At the time of writing, however, this report has not yet been released to the public.

1.1.2 Scope and Objectives of this Deliverable

This Deliverable 7.2 is part of Task 7.3, which, in turn, is part of Work Package 7 titled “Reducing Barriers”. Task 7.3 has as its objective to identify legal and regulatory challenges for the deployment of power-to-gas at the EU and national level. Task 7.3 is subdivided into two Deliverables. Deliverable 7.2 will present a review of EU legislation relevant to power-to-gas. Deliverable 7.3 will cover the national legislation of Germany, Switzerland and Italy and will include a review of the legislative modalities and complexities encountered by the three pilot sites. Together, Deliverable 7.2 and 7.3 will provide input for policy recommendations in the project-wide roadmap which will be drafted during the final stages of the project.

1.2 Relevance of EU Legislation for Switzerland

Switzerland is not a Member of the EU but of the European Free Trade Area (EFTA). The EFTA promotes free trade and economic integration among its four Member States (Iceland, Liechtenstein, Norway, and Switzerland). In the past, the EU and Switzerland have adopted multiple bilateral sectoral agreements, for example in the field of agriculture.[2] The EU has, however, declared its unwillingness to adopt new sectoral agreements in absence of a common institutional framework which governs existing and future agreements. Switzerland has expressed its preference for the ad hoc sectoral approach. The negotiations on such an institutional framework are still ongoing. In the meantime, negotiations on a bilateral electricity agreement, which would give Switzerland access to the EU internal electricity market, have been stalled.[2] As a consequence, the legislation presented in this Deliverable on the EU internal energy market does not (yet) apply to Switzerland. Nevertheless, in August of 2017 it was announced that the European Commission and Switzerland agreed to link their respective emission trading schemes.[3] It is now for the Council of the European Union and the European Parliament to approve this proposal.

[3] *See* BRIDGE Horizon 2020 website: www.h2020-bridge.eu.

2 Background on Power-to-Gas Technology and Functions

2.1 Introduction

The applicability and relevance of much of the legislation discussed in this Deliverable are often linked to specific processes, functions, modes of operation, and/or output of power-to-gas installations. Therefore, as a background to the review of the European legal and regulatory framework on power-to-gas, this Chapter provides a basic understanding of the technology (section 2.2) and functions (section 2.3) thereof.

2.2 Power-to-Gas Technology

Power-to-gas is the process through which, in a first stage, electrical power is used as input for the production of hydrogen (H_2) through the decomposition of a water molecule by electrolysis. The by-product of this process is oxygen (O_2) which can be released into the atmosphere.[4]

Equation stage (1): $2H_2O \rightarrow 2H_2 + O_2$

In an optional second stage, the hydrogen can be synthesised with carbon dioxide (CO_2) into methane (CH_4) through a catalytic Sabatier process, or through biological methanation.[4][1] The heat which is produced has a by-product due to the exothermic nature of the methanation process can be captured and utilised in various (industrial) applications.

Equation stage (2): $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$

The carbon dioxide required for the methanation stage can be obtained from a variety of sources such as industrial and power generating installations (fossil), biogas purification (biogenic), or the ambient air (ambient).[5] The concept “power-to-gas” used by industry or in the literature does not, however, always refer to this two-stage process, but can also refer to the single stage process of hydrogen production as end-product.

[6] Hydrogen in itself can be utilised in electricity generation and mobility through fuel cell technology, or serve as a feedstock for industrial applications. As illustrated in Figure 2-1, the emphasis within the STORE&GO project goes beyond the direct use of hydrogen. All STORE&GO plants apply the two-stage power-to-gas process for the production of SNG.

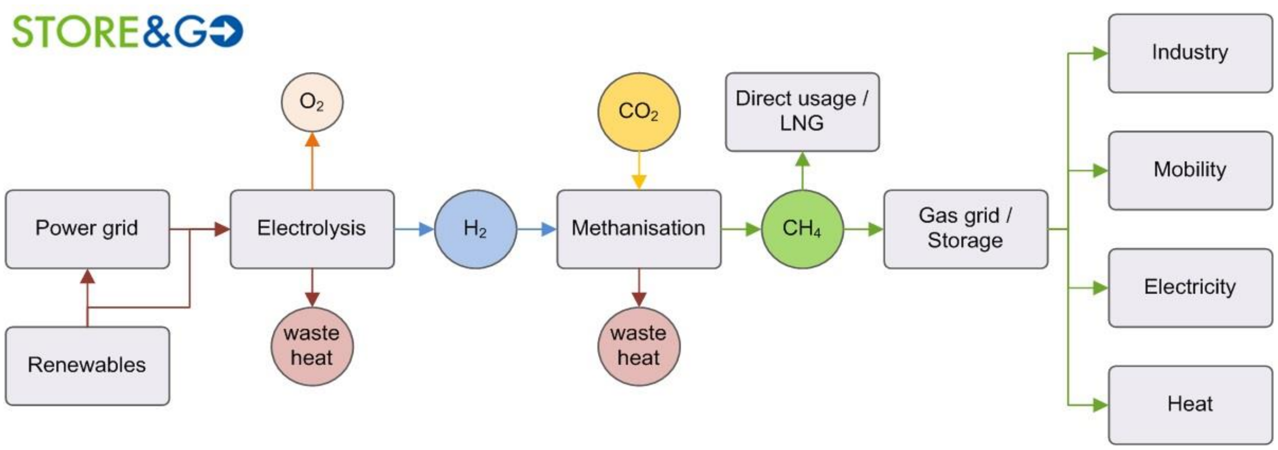

Figure 2-1: Overview of the power-to-gas supply chain (image by STORE&GO)

Both hydrogen and methane are gases with an high energy density, enabling the transportation and storage of large amounts of energy.[4] As the methane produced through power-to-gas is of a similar quality as natural gas, the gas produced through the two stage process is generally referred to as "synthetic" or "substitute natural gas" (SNG). The main advantage of producing SNG as end-product over hydrogen is that its similarities with natural gas allows for the transportation and storage thereof in the existing natural gas infrastructure.[1] In addition, the choice for SNG defers or avoids the direct need to modify or replace industrial and household appliances, which would be required in order to accommodate high levels of hydrogen in the gas system. In the long-term, the development and deployment of power-to-gas technology may also provide valuable experience for bridging the technological, economic and regulatory gaps towards an hydrogen economy.

As displayed in Table 2-1, the three STORE&GO demonstration sites in Falkenhagen (Germany), Solothurn (Switzerland), and Troia (Italy) have been designed and located in such a way as to test the operation of a power-to-gas plant under different local conditions. The configuration of the pilot sites differ in choice of electrolyser and methanation technologies, carbon sources, and electricity and gas grid conditions.

	Demonstration site Falkenhagen/Germany	**Demonstration site Solothurn/Switzerland**	**Demonstration site Troia/Italy**
Representative region with respect to typical generation of RES	Rural area in the North East of Germany with high wind power production and low overall electricity consumption	Municipal area in the Alps region with considerable RES from PV and hydro production	Rural are in the Mediterranean area with high PV capacities, considerable wind power production, low overall electricity consumption
Connection to the electricity grid	Transmission grid	Municipal distribution grid	Municipal distribution grid
Connection to the gas grid	Long distance transport grid	Municipal distribution grid	Regional LNG Distribution network via cryogenic trucks
Plant size (in relation to the el. power input)	1 MW	700 kW	200 kW
Methanation technology to be demonstrated	Isothermal catalytic honeycomb/structured wall reactors	Biological methanation	Modular milli-structured catalytic methanation reactors
CO_2 source	Biogas or bioethanol plant	Waste water treatment plant	CO_2 from atmosphere
Heat integration possibilities	Veneer mill	District heating	CO_2 enrichment
Existing facilities and infrastructure	2 MW alkaline electrolyser, hydrogen injection plant	350 kW PEM electrolyser, hydrogen injection plant, district heating, CHP plant	1000 kW alkaline electrolyser

Table 2-1: Overview STORE&GO demonstration sites

[4] The energy density of hydrogen and methane in mass is 120 MJ/kg and 50 MJ/kg respectively, in volume, 10,8 MJ/m^3 and 36 MJ/m^3 at 0 °C and 1 atmosphere pressure.

It is necessary for the later discussion in this Deliverable on the legal qualification of different output gases to distinguish between two power-to-gas concepts. The first concept can be described as a basic power-to-gas process, while the second concept combines power-to-gas with biogas upgrading. As will be further clarified below, where the energy content of the gas produced through the first basic concept is of a non-biological origin (electricity from solar or wind), the majority of the energy content in the second concept stems from biomass. This difference is decisive for the question whether a product gas can be defined as a biomass-based gas or fuel, or as a gas of a non-biological renewable origin, *see* Chapter 8. *See* for a detailed technical analysis of different power-to-gas technologies: [1], [4], [7], and [8].

Under the first power-to-gas concept, the carbon dioxide used for methanation is provided to the power-to-gas plant by an external source. The source of this carbon can be of a fossil, biogenic, or ambient nature. The *energy content* of the produced SNG is, however, not provided by the carbon dioxide, but by the hydrogen which is produced through electrolysis. It follows that the produced SNG is a gas of which the energy content is of a non-biological origin. This concept, as deployed by the three STORE&GO plants, is illustrated below in Figure 2-3.

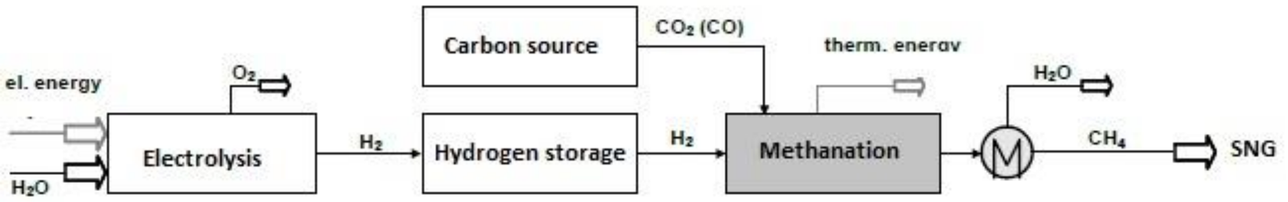

Figure 2-3: Overview of a power-to-gas chain (image by STORE&GO)

Under the second power-to-gas concept, the hydrogen produced by electrolysis is added to raw biogas produced through the anaerobic digestion of biomass in order to synthesise with the excess carbon therein. This is done in order to upgrade the methane content of raw biogas which typically contains around 50–70 percent methane and 30–40 percent carbon dioxide.[5] As gas quality standards and end-user appliances often require a gas with a methane content of at least 90 percent, carbon dioxide needs to be removed. However, instead of physically removing the carbon dioxide from the raw biogas, the carbon dioxide, together with the added hydrogen, can be converted into methane through biological methanation.[5] Importantly, the majority of the energy content of the output gas still stems from the anaerobic digestion of biomass, not from the added hydrogen produced through electrolysis. Therefore, it can be said that the energy content of this gas is primarily of a biological origin. Figure 2-4 and 2-5 provide a schematic overview of such biogas upgrading through power-to-gas. In Figure 2-4, biological methanation occurs within the digester. In Figure 2-5, the biogas is removed from the digester for upgrading through methanation in a separate reactor.

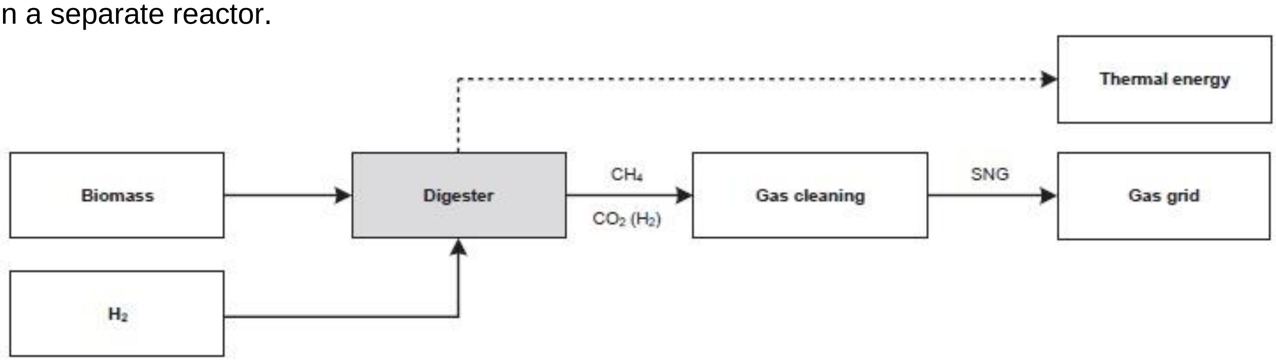

Figure 2-4: Biogas upgrading through biological methanation within the digester (image by [4])

[5] In the biological methanation process, a single-celled methanogenic archaea organism consumes the hydrogen and carbon dioxide and releases CH_4. The carbon source can be either fossil, biogenic, or ambient.

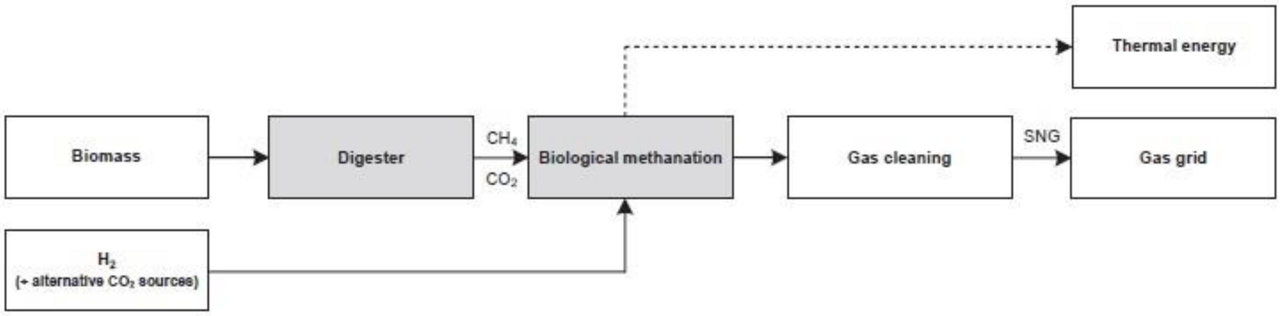

Figure 2-5: Biogas upgrading through biological methanation in a separate reactor (image by [4])

As the three STORE&GO pilot sites all fall under the first concept, the terms *power-to-gas* and *SNG* in this Deliverable are linked to this first concept. When referring to the second concept, the term *power-to-gas for biogas upgrading* will be used.

2.3 Functions of Power-to-Gas in the Energy System

Power-to-gas is generally referred to as an energy storage technology similar to flywheels, batteries, compressed air energy storage, and pumped hydro energy storage.[9] When power-to-gas conversion technology is combined with hydrogen fuel cells or flexible gas fuelled power plants, it can provide similar charge, storage, and discharge services to the electricity system as other storage technologies. Contrary to these technologies, however, power-to-gas is a multifunctional technology which is also capable of reaching out to sectors which are difficult to electrify. This section will provide an overview of the functions of power-to-gas both within the electricity system (section 2.3.1) as outside (section 2.3.2).

2.3.1 Power-to-Gas Providing Flexibility for the Electricity System

The most challenging task in the design and operation of future low-carbon energy systems will be to accommodate high shares of variable renewable energy sources while maintaining a high level of security of supply.[11] With regard to the availability of electricity, the non-alignment of the fluctuating output of electricity from solar and wind with actual demand requires solutions which can balance this disconnect on different time scales. Once in the system, the need to transport large amounts of electricity through the grid during peak load is expected to present further challenges for reliable grid operation, stability, and network congestion.[12] Excess supply of electricity has already led to periods of negative prices in the northern part of Germany and the need to curtail the output of wind farms.[13] It is expected that the urgency to address these challenges will increase in the future parallel to the growing share of renewable energy available within the European power system.[12][11]

The capacity of an energy system to cope with high shares of intermittent renewable energy will depend on the flexibility available in the system. Flexibility is the capability of an energy system, in this context the electricity system, to maintain a high level of security of supply in response to uncertainty and fluctuations in supply and/or demand.[11] This flexibility can be offered by means of different options:

- ***Supply-side flexibility:*** the curtailment of wind and solar installations and the provision of back-up capacity by peak and load following dispatchable power plants;
- ***Grid infrastructure expansion****:* construction of a dense copper plated European electricity network, including the expansion of the import and export capacity on interconnectors;
- ***Demand side response***: adaptation of consumption patterns by end-users;
- ***Energy storage*****:** time-shifting of the moment of delivery or use of produced energy.

A brief overview of the services and benefits that power-to-gas can provide is provided in the subsections below. A more detailed review of opportunities and options for power-to-gas in the electricity system is presented in Deliverable 6.1 of the STORE&GO project.

2.3.1.1 Ancillary Services

The first interface between the electricity system and a power-to-gas facility is the electrolyser. A dynamic operation of an electrolyser under its maximum capacity can provide both down- and upward ramping balancing or ancillary services to the transmission or distribution system.[10] This allows the power-to-gas operator to offer ancillary services such as frequency and voltage regulation, thereby assisting the system operator in maintaining the electricity grid in balance near real-time. Furthermore, when the production of hydrogen or SNG is coupled with a fuel cell, combined- or open-cycle gas turbine, or combined heat and power installation, an operator can provide additional non-frequency ancillary services such as spinning reserve, black start, peak load or load following.

2.3.1.2 Large-scale and Long-term Energy Storage

In times of excess supply of generated electricity, the conversion of electrons into molecules allows for the large-scale and long-term storage of energy. Hydrogen and SNG are both high density energy carriers which can be stored in tanks, pipelines or underground storage facilities.[6] In 2016, there were 149 underground gas storage facilities operational within the EU, with a combined natural gas storage capacity of 1182 TWh.[15] This large available storage capacity makes power-to-gas well suited for the seasonal storage of renewable energy in the European gas infrastructure.[16] As illustrated in Figure 2-6, power-to-gas thereby distinguishes itself from other energy storage technologies both in capacity as in the duration of discharging.

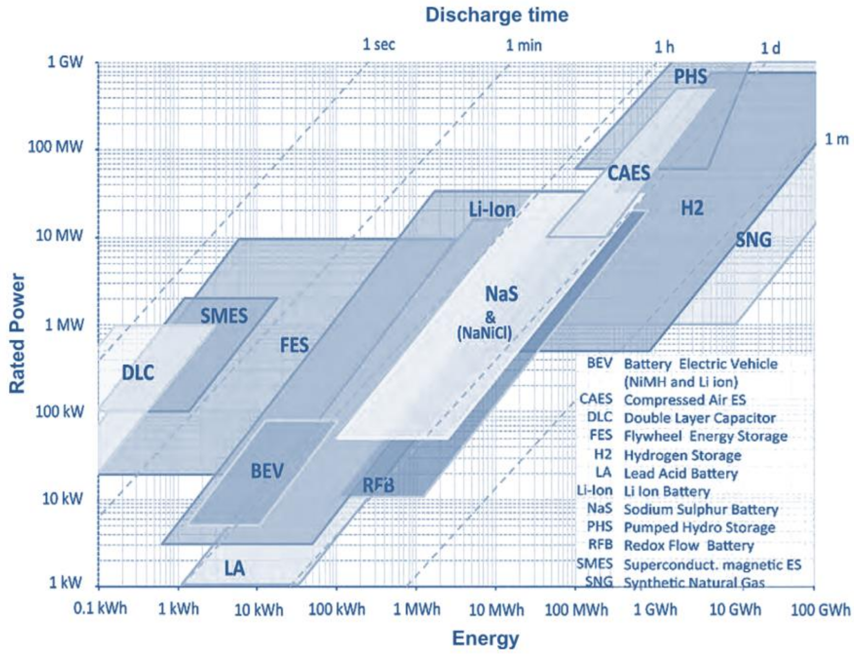

Figure 2-6: Comparison of storage technologies by discharge time and capacity (image by [17])

2.3.1.3 Enabling Integrated Hybrid Grid Infrastructure

The transportation of increasingly large amounts of decentralised generated electricity to consumption areas will lead to a more intensive use of electricity infrastructure and potential capacity constraints. [18] Therefore, in order to accommodate large flows of electricity during peak loads, extensive electricity grid expansions will be required. Besides the high costs which are associated with such expansions, the construction of above ground power lines can be met with opposition by the public ("Not In My Backyard").

[6] The energy density of hydrogen and methane in mass is 120MJ/kg and 50MJ/kg respectively, in volume, 10.8MJ/m^3 and 36 MJ/m^3 at 0 °C and 1 atmosphere pressure. In comparison, the energy density of gasoline (petrol) is 46.4MJ/kg.

An alternative for transporting energy from supply to demand locations as electrons, is to transport the energy as hydrogen or SNG through the existing gas infrastructure. Such shifting between infrastructures for the transport of energy may partially defer or replace the need for cost-inefficient electricity grid expansions. The technological link which is required for such shifting is provided by power-to-gas and gas-to-power technologies.[19] Together, these technologies establish a bi-directional link between the gas and electricity system.[20] This interlinkage provides opportunities for the joint and cost-efficient modelling and operation of an integrated hybrid energy grid. Hence, by enabling energy generated from wind and solar to be transported as a molecule through the extensive European gas grid, power-to-gas allows for the spatial balancing of energy, i.e. the transportation of energy from locations with energy surpluses to locations with an energy deficit.

2.3.2 Power-to-Gas for the Decarbonisation and Coupling of Energy Sectors

Parallel to the switch from fossils to renewables in the supply of energy, a persisting trend of electrification is expected in final energy demand.[21] Nevertheless, the European Commission expects the share of gas in final energy consumption in 2050 to be at 22 percent.[21] Considering that the share of gas in 2010 was at 24 percent, the decline in gas consumption is thus expected to be modest. Accordingly, there is much potential and need for the ‘greening’ of the gas molecules within the energy system in order to arrive at a low-carbon European economy.

By replacing gas from fossil sources for hydrogen and SNG, power-to-gas can make a considerable contribution towards the decarbonisation of sectors which will be difficult or inefficient to electrify.[1] Examples of such sectors are heavy and long-range transportation, high-temperature industrial applications, and dispatchable power generation. Furthermore, by offering these applications an alternative for natural gas, power-to-gas may contribute to the diversification and security of gas supply (*see* section 3.4). An extensive analysis of the potential future use and market uptake for hydrogen and SNG is presented by Workpackage 8 of the STORE&GO project.

3 European Union Energy and Climate Policy Framework for the Post-2020 Era

Key Findings

- European Union energy and climate targets, and security of energy supply, may become important drivers for power-to-gas
- The European Commission has developed a vision on energy storage and sectoral integration, while explicitly recognizing the benefits of power-to-gas
- According to the European Commission, energy storage needs to be able to participate fully in electricity markets on an equal footing with other flexibility providers

3.1 Introduction

European energy and climate policy, and eventually legislation, is founded on what is known as the "energy policy triangle".[22] The three themes giving shape to this triangle are "climate and the environment", "competition and affordability", and "security of supply". All three dimensions are addressed in the ambition of the European Commission to *"drive progress towards a low-carbon economy which ensures affordable energy for all consumers, economic growth and jobs, and reduced dependency on energy imports.*"[23] Another important driver for future EU energy and climate policy is the 2015 Paris Climate Agreement which has been ratified by the EU on October 5th 2016.[24] At the core of this agreement lies the long-term goal of limiting the rise of average global temperature to "well below" 2°C above industrial levels. This Chapter, in section 3.2, will first review which climate targets drive the EU energy and climate policy framework for the post-2020 era, and thus the shift towards a low-carbon economy. Subsequent section 3.3 will briefly discuss how the need to ensure security of energy supply in an energy system with increasingly high shares of intermittent renewable energy production may stimulate the deployment of power-to-gas. Finally, section 3.4 will set out the vision of the European Commission on energy storage and sectoral integration through power-to-gas.

3.2 European Union Energy and Climate Targets

An important mechanism for achieving a low-carbon European economy, and the deployment of low-carbon technologies as power-to-gas, is the setting of quantitative targets indicating the pace for decarbonisation and the minimum share of renewable energy in final consumption. In 2007 the European Council agreed on a set of three key targets which were to give direction to the EU 2020 climate and energy strategy. The so called "20-20-20 targets" aim at a 20% cut in greenhouse emissions relative to levels in 1990, a 20% share of renewables in the EU energy consumption, and a 20% improvement in energy efficiency.[25] Furthermore, the 2009 Renewable Energy Directive requires that 10 percent of the transport fuels consumed in every Member States have to come from renewable sources by 2020.[7] However, the expected horizon for the commercialisation and broad application of power-to-gas requires to look beyond 2020 to the European ambitions for the mid- and long-term.

The most relevant guidance document which displays the mid-term energy and climate vision of the EU is the 2014 communication by the European Commission tilted: *"A Policy Framework for Climate and energy in the Period from 2020 to 2030*".[23]. At the heart of the 2030 policy

[7] Article 3(4) of the 2009 Renewable Energy Directive (2009/28/EC).

framework lies, similar to the pre-2020 era, a trinity of key targets. The targets, which have been endorsed by the European Council in October 2014, aim for:

- At least 40% cuts in greenhouse gas emissions relative to1990 levels;
- At least 27% share of renewable energy in final energy consumption;
- At least 27% improvement in energy efficiency.

Contrary to the 20-20-20 targets which are to be achieved through the attainment of binding national targets, the 2030 targets for emission reduction and share of renewable energy are only binding at the EU-level. The exception is the 27 percent target for energy efficiency which is merely indicative. Although Member States will continue to be bound to their 2020 national targets, the achievement of the 2030 targets is thus above all a collective effort of all Member States. The achievement thereof will be monitored by the Commission under the proposed Energy Union Governance Regulation which is introduced under the Clean Energy Package.[27] Member States will be expected to submit every ten years, the first by 1 January 2019, an integrated national energy and climate plan in which they expound on their national objectives and targets regarding decarbonisation, energy efficiency, energy security, internal energy market, research and innovation, and competitiveness. If, however, the pace of progress towards the 2030 goals risks to put the achievement thereof in jeopardy, the Commission may issue necessary recommendations to the Member States and/or take measures at the EU-level.

For the long-term, the European Commission has declared its ambition in the Energy Roadmap 2050 which was published in 2011.[28] In this roadmap, the Commission suggests a 80–95 percent reduction of greenhouse gas emission compared to 1990 levels. Importantly, as one of the ten conditions for achieving a decarbonised energy system the 2050 Roadmap lists: *“[a] new sense of urgency and collective responsibility must be brought to bear on the development of new energy infrastructure and storage capacities across Europe and with neighbours.”* Energy storage is thus explicitly included in the long-term energy and climate vision of the EU.

3.3 Security of Energy Supply

Security of supply is one of the three dimensions of the energy policy triangle. This concept not only embodies the availability of supply, but also the capacity of energy networks to transport energy from production to consumptions locations.[30] Due to the increased electrification of the transport sector and building environment, security of electricity supply will become increasingly important.[8] In an energy system with high shares of variable electricity production from wind and solar, the availability of supply will no longer be primarily a matter of the availability of primary fuels, but of the availability of flexibility to cover (seasonal) swings in intermittent electricity supply.

As has been elaborated on in Chapter 2, power-to-gas can provide multiple functions which enhance the flexibility and security of supply of the electricity system. One of these functions is the large-scale storage of energy to cover seasonal swings in electricity production. In order to monitor and ensure the availability of electricity generation and supply, so called “resource adequacy” assessments will be required to be performed in the future at both the European and Member State level.[9] When Member States encounter resource adequacy concerns, they are required to consider the removal of regulatory distortions for, among others, energy storage.[10] This illustrates that security of energy supply may become an important driver for large-scale energy storage and thus power-to-gas.

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[8] Introductory text to the Recast Electricity Directive (COM(2016) 864 final/2).
[9] Article 18 and 19 of the Recast Electricity Regulation (COM(2016) 861 final/2).
[10] Article 18 (3) of the Recast Electricity Regulation (COM(2016) 861 final/2).

3.4 Vision on Energy Storage and Sectorial Integration Through Power-to-Gas

As discussed in Chapter 2, the transition from an economy based on fossil energy sources to an economy based on renewables is accompanied by new challenges associated with the integration of high shares of renewables with a variable output pattern. The need for flexibility within the energy system to address these challenges has prompted the European Commission to initiate multiple reviews on the value and internal market integration of energy storage technologies, including Power-to-gas.[9][31] The outcome of these studies made the Commission arrive at the conclusion that *"energy storage should be integrated into, and supported by, all relevant existing and future EU energy and climate measures and legislation"*.[31] This section will summarise the vision of the European Commission on energy storage and sectorial integration and role of power-to-gas therein. This vision forms the foundation for the analysis of the legal context in Chapter 5.

In order to adapt European energy and climate legislation to, amongst other issues, an energy system with high(er) shares of renewables, the European Commission in 2015 launched a public consultation process to come to a new energy market design.[47] Part of this process to involve industry stakeholders in the development of new legislation was the organisation by the Commission of a high level roundtable on the contribution of energy storage to energy security and the internal energy market.[34] Being one of the participants, E.ON presented the predecessor of the current STORE&GO project in Falkenhagen: "Windgas Falkenhagen". The focus of this project was on hydrogen production through water electrolysis and subsequent injection to the grid thereof. The idea that the debate on energy storage should be broader than the electricity context was also advocated by a representative from the Danish system operator*: [a] more unified European approach to storage would be beneficial. Energy storage is an element in the new energy system, not only in the electricity system"*. The general conclusion of this stakeholder session was that the existing market and legislative framework on energy storage was lagging behind the progress made by new technologies. Exemplary is the absence of a definition on energy storage in EU legislation governing the internal market in electricity.

Based on its own reviews, different stakeholder reports, and aforementioned roundtable on energy storage, the Commission has at the beginning of 2017 released an internal staff working document which provides insight into its vision on energy storage and sectorial integration.[35][11] In the document, titled *"Energy Storage – the Role of Electricity"*, the Commission acknowledges the potential functions and benefits of energy storage such as the cost-effective balancing of the variable generation profiles of renewables over various timeframes. Three passages containing a direct reference to the benefits of energy storage and sectorial integration through power-to-gas are in particular worth mentioning.

a) *"[S]torage can help reduce emissions from the conventional electricity generation: on the one hand by facilitating a more efficient use of the existing assets, on the other hand by reducing the carbon content of the fuels (e.g. blending of the natural gas with renewable hydrogen and synthetic methane)."* (*see* p. 7)

b) "*[S]ectorial integration will bring benefits to the electricity sector, as every step towards the decarbonisation objectives will have an increasing marginal cost if all the flexibility has to be found within the electricity sector itself. Thanks to sectorial integration, some flexibility and storage solutions could come from thermal systems, gas infrastructures, industrial feedstock and agriculture"*. (*see* p. 7)

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[11] Although Staff Working Documents provide information as to the position of the European Commission with regard to a certain topic, these documents have no formal status and are non-binding by nature.

c) *"Chemical storage and innovative sectorial integration could absorb almost all excess variable RES even in a high variable RES scenario".* (*see* p. 12)

To illustrate how sectoral integration may lead to synergies between different energy carriers, infrastructures, and applications, the Commission presents in the document a schematic overview of an integrated energy system, *see* figure 3-1.

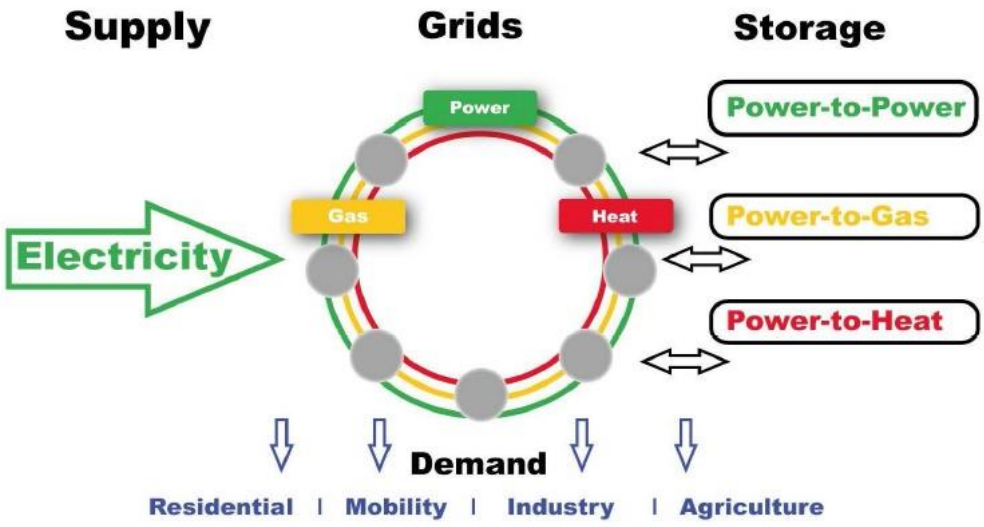

Figure 3-1: Illustration of a flexible and integrated energy system according to the European Commission (image by [35])

This integrated cross-sectoral view by the Commission on the future European energy system explains why it includes power-to-gas under the concept of energy storage even when the discharge of energy may occur outside the electricity sector. Instead of approaching the concept "energy storage" in a narrow way by merely focussing on the time-shifting of electricity, the concept of energy storage under this broad view aims at making the most efficient use of excess electricity in the energy system as a whole.

Finally, the staff working document on energy storage introduces four principles which should lead the way forward for energy storage and the commercialisation thereof:

1. Energy storage should be allowed to participate fully in electricity markets;
2. Energy storage should participate and be rewarded for services provided on equal footing to providers of flexibility services (demand response, flexible generation and adaptation of transmission/distribution infrastructure);
3. Energy storage can function as an enabler of higher amounts of variable RESs and could contribute to energy security and decarbonisation of the electricity system or of other economic sectors;
4. The cost-efficient use of decentralised storage and its integration into the system should be enabled in a non-discriminatory way by the regulatory framework.

4 Overview of European Energy Legislation

Key Findings

- Current EU energy law consists out of various EU Directives and Regulations on the internal market on electricity and gas and the promotion of renewable energy which entered into force in 2009, thereby replacing earlier Directives and Regulations. The current framework is also known as the "2009 Third Energy Package"
- The 2009 Gas Directive also applies to SNG in so far it can technically and safely be injected into, and transported through, the natural gas system
- The Clean Energy for all Europeans Package of 2016 contains legislative proposals for the revision of the 2009 Third Energy Package
- The Clean Energy for all Europeans Package is still under negotiation, provisions proposed therein may thus still be amended

4.1 Introduction

As power-to-gas is a technique under development which only recently has gained attention by policy makers, there exists no specific legislation thereon. However, the currently negotiated EU energy legislation for the post-2020 era will likely include several provisions on energy storage and non-biomass based gases from renewable sources. In order for the reader to oversee the legal EU energy framework and to better understand the legal debate in the subsequent Chapters, this Chapter will provide a brief overview of the various instruments which shape and will shape this domain of EU law. Section 4.2 will first introduce the current EU energy law framework under the so called "Third Energy Package". As European gas legislation primarily addresses natural gas, section 4.3 will review the applicability thereof to SNG. In section 4.4 recent legislative developments are discussed which will likely give shape to the future European legal framework on power-to-gas.

4.2 Current EU Energy Law: The 2009 Third Energy Package

It was not until the 1988 document "Towards an Internal Energy Market" that special attention was awarded to downstream electricity and gas markets, which at the time were dominated by integrated monopolistic companies which combined production, transportation, and supply within the same entity.[22][150] The need to regulate and liberalise the European electricity and gas markets has eventually led to sector-specific legislation on the internal energy market. The first generation of Directives stems from 1996 (electricity) and 1998 (gas). In 2003, these Directives have been replaced by new Directives on the internal market for electricity and gas and were accompanied by a 2003 Regulation on electricity and a 2005 Regulation on gas which in particularly focus on cross-border trade. The 2003 Electricity and Gas Directives aimed at completing the internal market for electricity and gas by increasing the freedom for consumers to choose the supplier of their choice and the further unbundling of energy transport and production activities. As, however, the 2003 legislation fell short in realising a sufficiently liberalised, competitive, and integrated internal energy market, new legislation was again introduced in 2009.[22] The content of this package, known as the Third Energy Package, is still the law of today.

The 2009 Third Energy Package consists out of the following pieces of legislation:

- Directive 2009/72/EC concerning common rules for the internal market in electricity (hereafter "**2009 Electricity Directive**");
- Regulation (EC) No 714/2009 on conditions for access to the network for cross-border exchanges in electricity (hereafter "2009 Electricity Regulation");
- Directive 2009/73/EC concerning common rules for the internal market in natural gas (hereafter "**2009 Gas Directive**");
- Regulation (EC) No 715/2009 on conditions for access to the natural gas transmission networks (hereafter "**2009 Gas Regulation**");
- Directive 2009/28/EC on the promotion of the use of energy from renewable sources (hereafter "**2009 Renewable Energy Directive**").

Importantly, where rules contained in Directives need to be transposed into national law, provisions under the Regulations are directly applicable in the territory of the Member States.

The 2009 Electricity and Gas Directives and Regulations all aim at increasing competitiveness and market integration.[22] In order to arrive at an integrated internal electricity market, the 2009 Electricity and Gas Directives establish common rules for the generation, transmission, and distribution of electricity. Specific rules for the cross-border trade in electricity and are provided by the respective 2009 Electricity/Gas Regulation. These Electricity and Gas Directives and Regulations will be discussed in the power-to-gas context in Chapter 5 (ownership and operation of power-to-gas facilities), Chapter 6 (influence of electricity market design) and Chapter 7 (access to the gas network and gas quality standards).

The 2009 Renewable Energy Directive aims at promoting the use of renewable energy. It sets mandatory national targets for the achievement of the aforementioned Union-wide targets for 2020. In addition, the Directive lays down rules on guarantees of origin, simplified administrative procedures, incentives for the use of energy from renewable sources, and sustainability criteria for bio-based fuels.[12] The relevance of the Renewable Energy Directive to power-to-gas is covered under Chapter 8.

Finally, the 2009 Electricity and Gas Regulations prescribe the need for the development of binding European network codes and guidelines relating to a variety of topics contributing to market integration.[22][13] These codes and guidelines are developed by the European Network of Transmission System Operators for Electricity or Gas (ENTSO-E/G) based on the guidelines by the Agency for the Cooperation of Energy Regulators (ACER). After the adoption of these network codes by the European Commission and a committee of experts from the Member States, these need to be approved by the Council of the European Union and the Parliament. When approved, the codes and guidelines constitute legally binding and directly applicable pieces of legislation for the Member States. An example of a guideline relevant to power-to-gas is the recently adopted Guideline on Electricity Balancing (*see* section 6.4)

4.3 Applicability of the 2009 Gas Directive

The title of the 2009 Gas Directive states that the Directive concerns *"common rules for the internal market in natural gas"*. The Directive establishes common rules for the transmission, distribution, supply, and storage of natural gas.[14] As the heading only contains a reference to *natural gas,* it needs to be assessed to what extent the 2009 Gas Directive also applies to SNG. As to its scope,

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[12] Article 1 of the 2009 Renewable Energy Directive (2009/28/EC).
[13] Article 6 of both the 2009 Electricity Regulation (EC) No 714/2009 and 2009 Gas Regulation (EC) No 715/2009.
[14] Article 1(1) of the 2009 Gas Directive (2009/73/EC).

the 2009 Gas Directive states that: *“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”*.[15] Accordingly, the technical and safety standards applicable to the injection and transportation of gas through the natural gas system, including gas quality standards, form the benchmark with which other gases need to comply. In absence of European harmonised legislation on gas quality standards, the Member States maintain discretion to establish these technical and safety norms and conditions for gas injection (*see* section 7.3 for discussion on gas quality harmonisation).

What follows from the above is that when the chemical composition of SNG is fully analogue to that of natural gas, the 2009 Gas Directive applies to the transmission, distribution, supply and storage thereof. Although only relevant for the single stage power-to-gas process, the answer to the question whether the rules on natural gas also apply to the blending of hydrogen into the natural gas flow is less straight forward. The discussion on the technical and safety boundaries for injecting hydrogen into the natural gas flow is not yet resolved.[36] It could be argued that the 2009 Gas Directive applies to the extent that the legal standard for the maximum allowed volume of hydrogen is not exceeded. A EU wide hydrogen admixture standard, in combination with a clarification of the applicability of the 2009 Gas Directive to hydrogen, is recommended in this regard.

4.4 Recent Legislative Developments: “Clean Energy for all Europeans”

Similar to the energy system as a whole, European energy law is on the move. The year 2016 revealed that also the 2009 Third Energy Package has an expiration date. At the end of November of this year, the European Commission presented the *“Clean Energy for All Europeans Package”* (Clean Energy Package).[16] This package, also commonly referred to as the *“Winter Package”*, is an extensive collection of legislative proposals. It includes revisions of the 2009 Electricity Directive and Regulation, and the 2009 Renewable Energy Directive.[17] As this Deliverable will discuss both the current legislation and the 2016 proposals, the lack of a clear distinct system of reference may leave the reader confused. To prevent such confusion, all legislative proposals introduced by the Clean Energy Package will be preceded by the term “Recast”, e.g. “Recast Electricity Directive”.

It is clear from these legislative developments that the European Commission has been very active in introducing legislative proposals on energy for the post-2020 era. It is important, however, to bear in mind that it is not the European Commission who eventually decides on the definite content of legislation. It are the Council of the European Union and the European parliament who need to come to a consensus on a final text for each individual Directive or Regulation. For the Clean Energy Package, this negotiation and adoption process has only recently commenced and may take up to two years to finalise. As such, the various legislative proposals discussed in this Deliverable may still be subjected to change. Progress in the adoption of all legislative proposals can be tracked through the “legislative train schedule” from the European Parliament. The design of the website alone makes it well worth a visit.[18]

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[15] Article 1(2) of the 2009 Gas Directive (2009/73/EC).

[16] *See*, https://ec.europa.eu/energy/en/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition.

[17] This Deliverable will cover proposals for a Recast Renewable Energy Directive COM(2016) 767 final/2; Recast Recast Electricity Regulation COM(2016) 861 final/2; and Recast Electricity Directive COM(2016) 864 final/2.

[18] *See*, http://www.europarl.europa.eu/legislative-train/theme-resilient-energy-union-with-a-climate-change-policy.

Notably, the Clean Energy Package does not contain a revision of the rules on the internal gas market contained in the 2009 Gas Directive and Regulation. The European Commission has, however, recently launched a so called *quo vadis* study on the gas market regulatory framework. Various stakeholder have already provided the Commission with input.[19] As the Latin term "*quo vadis*" stands for "where are we going?", it may well be that the outcome of this study will result in a revision of the 2009 Gas Directive.

[19] *See,* http://ec.europa.eu/energy/en/studies/study-quo-vadis-gas-market-regulatory-framework.

5 Classification, Ownership and Operation of Power-to-Gas Facilities

Key Findings

- The 2009 Third Energy Package contains no definitions of energy storage or power-to-gas, or specific rules on who is allowed ownership of such facilities
- In absence of specific rules defining and classifying power-to-gas, the conversion of electrical energy to SNG can be considered a gas production activity
- When power-to-gas is a production activity, the unbundling rules under the 2009 Third Energy Package do not allow system operators or gas storage system operators to operate such a facility
- It is likely that power-to-gas falls under the scope of the proposed definition and ownership regime on energy storage under the Recast Electricity Directive
- Ambiguities remain on what should be considered to be the energy storage facility in the power-to-gas context, and how the unbundling rules applicable to power-to-gas as energy storage under the Recast Electricity Directive align with similar rules on power-to-gas under the 2009 Gas Directive

5.1 Introduction

This Chapter will assess how power-to-gas and power-to-gas facilities can be classified in light of the 2009 *and* Recast Electricity Directive and the 2009 Gas Directive, and who is allowed to own and operate such a facility. The concept of power-to-gas is primarily covered under multiple reports and communications by the European institutions as an energy storage technology.[9][31][35][37] Similarly, various stakeholder papers and academic publications discuss power-to-gas in the context of large scale energy storage.[4][16][38][39] power-to-gas could indeed be deployed by generators of electricity to remedy the intermittent production pattern of their assets. Alternatively, gas storage system operators, which are already operating a natural gas storage facility, may want to offer energy storage services through power-to-gas. In addition, also system operators may be interested to control an electrolyser in order to resolve unbalances or congestion in the electricity grid. However, as the current legal framework under the Third Energy Package lacks rules addressing the question who is allowed to own/operate energy storage facilities, there is a need for new rules addressing this matter. These rules have now been proposed under the Recast Electricity Directive.

Before discussing these proposed rules on energy storage under the Recast Electricity Directive in section 5.3, section 5.2 aims to assess how current EU energy law classifies power-to-gas. As discussed in Chapter 2, power-to-gas has more potential functions than the mere time-shifting of a certain quantity of generated electricity. As will be argued in section 5.2, looking at power-to-gas from the perspective of the gas sector, the conversion of electrons into molecules, which are then injected into the natural gas grid, may also be considered a gas production activity. If so, then the rules under the 2009 Gas Directive on who is allowed to own and operate certain assets must also be taken into consideration. Finally, section 5.4 will discuss certain legal ambiguities which remain to exist regarding the allowed ownership and control of power-to-gas facilities.

5.2 Unbundling of Power-to-Gas under the 2009 Third Energy Package

The purpose of this section is to discuss how current EU energy law stemming from 2009 classifies power-to-gas, and to assess which entities in the energy sector would be allowed to own and operate a power-to-gas facility. It needs to be stressed again that the current legal framework does not address the concept of energy storage in the electricity context or power-to-gas. How power-to-gas and the 2009 legal framework relate to the proposed legal framework on energy storage under the Clean Energy Package will be discussed later in section 5.3 and 5.4.

With regard to the classification of power-to-gas under the 2009 framework, the question is how to define the activity of converting electrons into SNG through electrolysis and methanation. Looking at the functions of production, transmission, distribution, storage, and supply, it can be argued from the general concept of "production" that the manufacturing of SNG from hydrogen and carbon dioxide is a production activity.[20] The term "production" in the gas context is, however, not defined under EU energy law. Nevertheless, there is no clear argument why, under the current legal framework, the conversion of electrons into SNG should not be considered a production activity, similar to the extraction of natural gas from underground reservoirs, or the production of (upgraded) biogas from biomass. It would, however, be useful if the EU legislator clarifies the term "production" in the future while taking note of the introduction of new (synthetic) gas production processes such as power-to-gas. Building on the suggestion that the conversion of electricity into SNG through electrolysis and methanation is a gas production process, the question is then: which entities may perform this activity?

5.2.1 Ownership and Operation by Transmission or Distribution System Operators

A first scenario which will be examined is the ownership and operation of a power-to-gas facility by a transmission or distribution system operator. Whether this would be allowed needs to be reviewed by looking at the rules on the unbundling of the energy sector. The 2009 Electricity Directive and the 2009 Gas Directive contain rules which prescribe that the ownership and operation of electricity and gas networks needs to be unbundled from production and supply activities. The idea behind such unbundling is that a separation of transport and production activities results in the neutral operation of, and open access to, energy transportation infrastructure, and the establishment of competitive electricity and gas markets.[21] The introduction of the unbundling rules meant a restructuring of vertically integrated companies, i.e. undertakings or a group of undertakings performing at least one of the functions of transmission or distribution and at least one of the functions on generation or supply.[22]

With regard to the separation of electricity and gas transmission activities from production and supply activities, both the 2009 Electricity- and Gas Directive allow Member States to choose between three different unbundling models:

1. *strict ownership unbundling*: the same legal person, for example a holding company, is prohibited to simultaneously exercise control over a production or supply undertaking, and over a transmission system or system operator, and *vice versa*;
2. *independent system operator* (ISO model): ownership of the network may remain within the vertically integrated company, however, an independent system operator must be appointed who controls the operation of the network;
3. *independent transmission system operator* (ITO model): both the ownership of the network and the operation thereof remain within the vertically integrated company, however, various

[20] The Oxford Dictionary defines "production" as: *"the action of making or manufacturing from components or raw materials, or the process of being so manufactured".*

[21] *See* Recital sections of the 2009 Electricity and Gas Directives (2009/72/EC and 2009/73EC).

[22] Article 2(21) of the 2009 Electricity Directive (2009/72/EC).

stringent rules in the Directives must be followed to ensure the independency of the system operator.[23]

At the distribution level, there exists no prohibition of combined ownership/control by the same legal person over a production or supply undertaking and over a distribution system or system operator. However, the 2009 Directives do prescribe that where a distribution system operator is part of such a vertically integrated company, it must be independent at least in terms of its legal form, organisation, and decision-making.[24] This includes the need for a distribution system operator to a have to its disposal the necessary resources, including human, technical, physical and financial resources.

Importantly, under none of the three unbundling models at the transmission level, or the requirements at the distribution level, is it allowed for system operators themselves to take direct control over production activities. As a consequence, when following the line of thought that power-to-gas may constitute a gas production activity, system operators are not allowed to operate such a facility. Whether the same legal person would then be allowed to exercise control over both a transmission system/transmission system operator and an undertaking operating a power-to-gas facility would depend on the unbundling model opted for by a Member State.

5.2.2 Ownership and Operation by Gas Storage System Operators

A second scenario could be that an operator of a gas storage facility would simultaneously control operations in a power-to-gas facility in order to offer both conversion and gas storage services. Although rules on energy storage in the electricity context are absent under the 2009 Directives, the storage of energy is not new. Provisions on the operation of gas storage facilities were already included under the 1998 Gas Directive. Under the current 2009 Gas Directive, a gas storage facility is treated as a separate asset besides transportation infrastructure and production installations.[25] Such a gas storage facility is defined as a *"facility used for the stocking of natural gas and owned and/or operated by a natural gas undertaking."*[26] It is highly unlikely that the conversion of energy from an electrical to a gaseous state falls under the "stocking of natural gas" and would be considered a gas storage activity. Although SNG may indeed be stocked in natural gas facilities because of the compositional similarity with natural gas, the actual power-to-gas conversion process may also take place without such subsequent storage. As argued, in absence of a provision stating otherwise, the term "production" seems to be a more appropriate classification of the power-to-gas process.

For gas storage system operators, the consequence of classifying a power-to-gas facility as a production installation is that they are not allowed to operate such a facility. The Gas 2009 Directive establishes a specific unbundling regime for gas storage system operators: a gas storage system operator must be independent in its legal form, organisation, and decision making from entities which produce or supply gas.[27] Together with the requirement that Member States need to impose a regime which allows access for third parties to a storage facility, this unbundling of production and storage activities needs to ensure that the scarce capacity of underground storage facilities is available to all market parties.[28] This explains why energy undertakings operate their gas storage facilities through a separate subsidiary and an independent storage system

[23] Articles 9(1), 13, and 26 of the 2009 Electricity Directive (2009/72/EC).
[24] Article 26 of both the 2009 Electricity Directive (2009/72/EC) and the 2009 Gas Directive (2009/73/EC).
[25] Article 2(9) of the 2009 Gas Directive (2009/73/EC).
[26] Article 2(9) of the 2009 Gas Directive (2009/73/EC).
[27] Article 15 of the 2009 Gas Directive (2009/73/EC).
[28] Article 33 of the 2009 Gas Directive (2009/73/EC).

operator.[15] Energy companies would thus be obligated to structure the operation of a power-to-gas plant and of a gas storage facility under different subsidiaries.

5.3 Developments on a Legal Framework on Energy Storage

This section will review the legal framework on energy storage under the Clean Energy Package of 2016 and will examine to what extent this definition also applies to power-to-gas, even when the stored energy is not discharged in the electricity system. Subsequently, the proposed specific ownership regime for energy storage facilities is described.

5.3.1 Definition on Energy Storage

As energy storage in support of renewable energy production was not an important issue in the 2009 energy landscape, the then adopted legal framework contains only scarce reference to such energy storage. The 2009 Renewable Energy Directive mentions the need to support the use of energy storage systems for intermittent production of energy from renewable energy sources.[29] It also prescribes that Member States shall take the appropriate steps to develop, besides intelligent and robust networks, storage facilities.[30] Further guidance on which entities are actually allowed to develop and operate such systems is, however, lacking.

Recent reports and industry stakeholder views on energy storage have argued that the absence of a legal framework on energy storage is cause for concern for potential investors and may eventually hamper its deployment (*see* [9],[34],[38],[39],[40],[41],[42],and [43]) As the issue of the highest priority, the European Commission has been called upon to provide a definition on the concept of energy storage. Such a definition could clarify whether energy storage in the electricity context should be considered a separate asset category alongside production, transportation, and consumption, as argued for by the European Parliament.[44] Furthermore, a definition could shed light on the question whether the concept embraces the conversion and storage of generated electricity for purposes other than re-electrification. If the answer to this last question is affirmative, this would be in line with the technological pluralism among storage technologies which are not limited to Power-to-Power solutions, but include power-to-gas and Power-to-Heat. This would give evidence of an integrated view on the energy system in conformity with the vision on sectoral integration by the European Commission as discussed under section 3.3.

The European Commission Directorate-General for Energy has issued in June 2016 a document titled *"Energy Storage – Proposed Policy Principles and Definition*".[45] On the design of a legal definition on energy storage the document states: "*Electricity can also be converted to heat or gas and stored for a subsequent use in heating, mobility or industry. To enable an optimal and cost-effective contribution from these storage solutions a broader understanding in defining storage appears to be required."* Building on this reflection, the document proposes the following definition:

> *"Energy storage in the electricity system is the act of deferring an amount of the energy that was generated to the moment of use, either as final energy or converted into another energy carrier."* (underlining added)

In the final version of the definition as included in the Recast Electricity Directive the underlined term "energy" has been replaced by "electricity". Article 2(47) of this Directive now reads:

[29] Recital 57 of the 2009 of the Renewable Energy Directive (2009/28/EC).
[30] Article 16(1) of the 2009 Renewable Energy Directive (2009/28/EC).

> *“'Energy storage' means, in the electricity system, deferring an amount of the electricity that was generated to the moment of use, either as final energy or converted into another energy carrier.”* (underlining added)

In absence of an explanatory note, it is unknown whether the Commission exchanged the term “energy” for “electricity” with the intention to alter or limit the scope of the definition. What can be observed, however, is that the definition in itself does not unequivocally state whether power-to-gas is covered under the definition on energy storage if the gases produced are not reconverted into electrical energy. The phrase “*either as final energy or converted into another energy carrier”* could refer to the terms “deferring”, “use” or both. When only linked to the term “deferring”, the phrase would constitute a mere recognition of the different forms in which energy can be temporarily stored (e.g. kinetic, electro-magnetic, or chemical) without clarifying whether this energy needs to be reconverted into electricity or not.

A more unambiguous definition of energy storage is provided by the European Parliament in a committee draft report in response to the proposal by the Commission. This definition embraces in unambiguous terms the full concept of power-to-gas:

> *“'Energy storage' means, in the electricity system, the conversion of electrical energy into a form of energy which can be stored, the storing of that energy, and the subsequent reconversion of that energy back into electrical energy or another energy carrier.”*[46]

As already apparent from the amendment proposed by the European parliament, the formulation of a definition on energy storage is part of the ongoing legislative process. Therefore, the exact scope of the eventually adopted definition remains uncertain.

5.3.2 Right to Own and Operate Energy Storage Facilities

5.3.2.1 Different Models for the Ownership of Energy Storage Facilities

In section 5.1, an overview has been provided of the existing unbundling rules for the European electricity and gas sector. In the recent regulatory debate on the unbundling of energy storage activities, different ownership models have been brought forward. Legislators can opt for a model in which ownership is exclusively reserved for market parties, including independent third parties, or choose for a model in which (conditional) ownership and control is allowed by regulated entities (system operators).

An argument in favour of exclusive ownership by market parties is that a profitable deployment of storage requires the aggregation of services and income streams.[48] An important income stream, besides participating in wholesale energy markets, is the possibility to offer frequency and non-frequency ancillary services to system operators without the latter having the possibility provide the services to itself. This has also been shown for power-to-gas.[49] Furthermore, the operation of large capacity energy storage facilities bears the risk of preferential treatment thereof during dispatch compared to a facility owned by another party.[43] This could lead to similar competition distortive effects as the combined ownership of generation and transmission or distribution assets by vertical integrated companies prior to the liberalisation of the European electricity market. System operators still part of a vertically integrated company could favour affiliated production or supply companies when deciding on access to, or the booking of capacity with, an energy storage facility. This first model is implemented in the United Kingdom where energy storage is treated as a generation asset. Large scale pumped hydro storage facilities are, therefore, required to operate under a generation licence.[31]

Arguing in favour of the second model, several organisations for distribution system operators have suggested that regulated ownership should be allowed for low-capacity storage systems which are solely deployed in support of system stability or congestion relieve.[41] Under such conditions, the risk of a distorting effect on competitive markets would be limited or prevented. This view is also advocated by Terna, an Italian transmission system operator, which has suggested that the issue of ownership should not focus on the ownership of storage facilities as an asset, but rather on the services which such facilities is intended to provide.[34] Terna's position is a reflection of the current Italian law which determines that transmission system operators are allowed to build and manage "diffused storage systems" if required as reinforcement to ensure that renewable generation is optimally dispatched.[32]

A somewhat more nuanced position has been brought forward by ENTSO-E, which has proposed that the starting point should be that storage services are provided through competitive markets.[51] However, where these markets, and thus storage services, do not develop, the market could be stimulated by regulated long-term contracts or investments by the system operator. In the latter case, the system operator could auction the capacity of the storage system to the markets, similar to the capacity of interconnectors.

A final approach worth mentioning, similar to the one eventually opted for by the European Commission, is the model under the Belgian Electricity Act. This model allows for ownership by system operators if the following conditions are met:

a) the electricity is generated for balancing purposes only, with an explicit prohibition for commercial purposes;
b) the stored electricity is called upon as a last resource;
c) under the form of negotiated drawing rights;
d) to the limit of the power needed for ancillary services;
e) upon the prior approval of the regulator;
f) after having completed all relevant procedures for calling upon the market.[33]

5.3.2.2 Ownership of Energy Storage under the Recast Electricity Directive

Having listened to the call by the industry for legal certainty regarding energy storage, the European Commission has introduced a dedicated provision in the Recast Electricity Directive on the ownership of energy storage facilities for both the transmission (Article 54) and the distribution level (Article 36). These provisions reflect the view by the Commission that the ownership and operation of energy storage facilities is considered to be a commercial activity which should, in the first place, be performed by market parties instead of regulated entities.[35] Both provisions state as a basic rule: *"system operators shall not be allowed to own, manage or operate energy storage facilities".* Member States may, however, derogate from this basic rule, by allowing transmission and distribution system operators ownership, when the following conditions are met:

a) the market, following an open and transparent tender procedure, should not have expressed their interest in owning, controlling or operating a storage facility;
b) the deployment of a storage facility should be necessary for system operators to fulfil its obligations under the Recast Electricity Directive for the efficient, reliable, and secure operation of the system, and;

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[31] Article 4*ff* Electricity Act 1989.
[32] Legislative Decree 28/11 implementing the Renewable Energy Directive (2009/28/EC) and Legislative Decree 96/11.
[33] Article 9(1) of the Wet van 29 April 1999 betreffende de organisatie van de elektriciteitsmarkt (Belgian Electricity Act of 1999).

c) the national regulatory authority needs to assess the necessity of a derogation while taking account of the first two conditions and has to grant its approval.

For the transmission level, additional criteria are prescribed:

d) system operators are denied the possibility to sell the stored electricity to the market;
e) the decision to grant a derogation needs to be notified to ACER and the European Commission along with the reasons for granting the derogation.

For both the transmission and distribution level, the system operator which operates a facility by derogation is required to perform at regular intervals, or at least every five years, a public consultation in order to assess whether market parties are interested to take over the storage activity in a cost-effective manner.[34]

Importantly, Article 54 does not only limit the ownership and control of transmission system operators over energy storage facilities, it also states that these operators are not allowed to directly or indirectly control assets that provide ancillary services. Although a similar derogation from this rule is allowed as for storage facilities, this derogation is limited to the extent that it only covers assets providing non-frequency ancillary services (*see* section 6.4 on the use of power-to-gas for the provision on frequency ancillary services). Non-frequency ancillary services are those services used by a transmission or distribution system operator for steady state voltage control, fast reactive current injections, inertia and black start capability.[35] This exclusion of a derogation for assets which provide frequency ancillary services is a further limitation of the context in which system operators may deploy energy storage facilities.

The ownership model opted for by the European Commission is a reflection of the four principles which collectively affirmed that energy storage should be allowed to participate fully in electricity markets (*see* section 3.4). This market-first approach (no regulated ownership, unless) requires energy storage to compete in energy wholesale and balancing markets with other flexibility providers in order to come to the most cost-effective solution for the integration of variable renewable energy. Simultaneously, the possibility for derogations allow system operators to ensure themselves of the benefits of storage for grid operation when the market is absent, immature, or passive. How lenient or stringent this derogation may be applied will to a large extent dependent on how the national regulatory authorities interpret the necessity under point (b). The European Commission has, however, put itself and ACER in a monitoring position by including a notification obligation for Member States when a derogation has been approved at the transmission level. This would allow ACER or the Commission to develop guidelines or an interpretive note in the future in order to promote the homogenous implementation of the ownership regime on energy storage under the Recast Electricity Directive.[36]

5.4 Ambiguities on the Classification, Ownership, and Operation of Power-to-Gas Facilities

Based on the discussion in the previous section, it can be concluded that it is likely that an eventually adopted definition on energy storage under the Recast Electricity Directive also applies to power-to-gas, even when the SNG is not reconverted into electricity. The presented statements and proposed definitions by the European Commission and Parliament seem to support such a cross-sectoral approach. This would mean that transmission and distribution system operators are only allowed to own and control a power-to-gas facility if a market is absent, or shows no interest. Although the acknowledgement of power-to-gas as energy storage technology ensures that this

[34] Article 54(4) of the Recast Electricity Directive (COM 864 final/2).
[35] Article 2(38) of the Recast Electricity Directive (COM 864 final/2).
[36] Such an interpretive note has already been issued in the past on the unbundling and third party access regime for gas storage facilities.

technology is treated equal to other technologies such as pumped hydro storage, compressed air energy storage, or batteries, a few ambiguities still need to be solved.

A. Definition of "Energy Storage Facility" in the Context of Power-to-Gas

Contrary to other energy storage technologies such as batteries or compressed air storage, the charging, storage and discharging of energy by through power-to-gas may occur at dispersed locations. Figure 5-1 provides examples of how a power-to-gas plant, gas storage facility, and Gas-to-Power plant may be linked in the energy storage chain, but nevertheless located at dispersed locations. The dispersed locations are indicated through the coloured boxes.

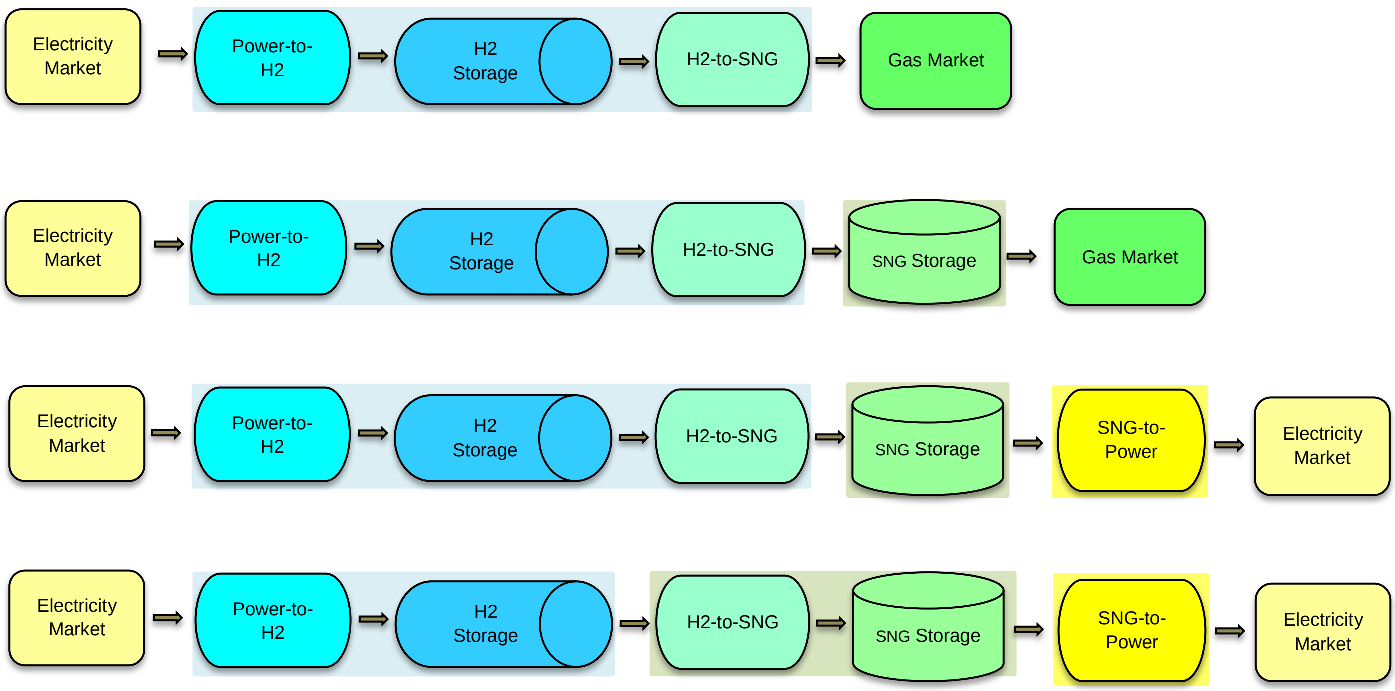

Figure 5-1: Examples of power-to-gas and related activities. The boxed areas represent dispersed locations. (image by author)

As illustrated in Figure 5-1, the power-to-gas chain can consist out of multiple (optional) tiers. Although the conversion of power to hydrogen and SNG will often occur within the same installation, the gas storage facility and optional gas-to-power facility may be situated elsewhere. Such distribution of activities over geographically dispersed areas allows for the optimal deployment of a power-to-gas energy storage chain based on where electricity surpluses and network congestion occur (charging), the availability of underground gas storage capacity (storage), and location of energy demand (discharging). Moreover, as already mentioned under 2.3.1.3, this also allows for the transportation of energy over longer distances as molecules, thereby partially deferring or replacing the need for cost-inefficient electricity grid expansions.

The potential involvement of different types of activities and assets at dispersed locations may require a clear delimited definition of an energy storage facility in the Recast Electricity Directive.

B. Conditional Ownership and Operation of Power-to-Gas Energy Storage Facility

The complexity of the discussion on unbundling in the context of power-to-gas is enhanced by the existence of parallel European electricity and gas legislation. Taking the perspective of a power-to-gas plant as energy storage facility under the Recast Electricity Directive, the ownership rules as proposed under the Recast Electricity Directive allow for the conditional ownership and operation thereof by transmission or distribution system operators in absence of interest by the market.[37] However, as concluded under section 5.2, such conditional control over operations would not be allowed when the power-to-gas conversion process is simultaneously considered a production activity. The possibility for system operators to take direct control over production facilities is unconditionally excluded under the unbundling rules in the 2009 Electricity- and Gas Directives.[38] When a Member State has introduced a strict ownership unbundling regime, a system operator and a gas production plant may not even be allowed to be part of the same group of undertakings, even when these are structured under separate subsidiaries.[39]

This collision of different definitions and correlated unbundling regimes in relation to power-to-gas under the Recast Electricity Directive and the 2009 Gas Directive may lead to legal uncertainties. It would thus be necessary for the European legislator to clarify how the concept of energy storage relates to possible other classifications of power-to-gas.

C. Combined Ownership of a Power-to-Gas Energy Storage Facility and a Gas Storage facility

There is no existing or proposed provision prohibiting a gas storage system operator to also operate an energy storage facility in the context of the Recast Electricity Directive. This already occurs in practice and makes sense on the ground that large quantities of energy can be stored in underground gas storage facilities. However, as discussed under 5.2.1.3, a gas storage system operator would not be allowed to operate a power-to-gas energy storage facility when such an operation also results in the production of gas.[40] Similarly to the ambiguity surrounding the conditional ownership and control of power-to-gas facilities by system operators, clarification on whether power-to-gas constitutes a gas production asset besides being an energy storage activity is required to resolve legal uncertainty.

In conclusion, it can be recommended to the European legislator to align the legal framework for energy storage under the Recast Electricity Directive with the 2009 Gas Directive in order to prevent ambiguities regarding the operation of power-to-gas facilities and related activities. In the future, a single Directive covering both the internal market for gas and electricity may reflect the increasing sectoral integration in the energy sector.

[37] Article 36 and 54 of the Recast Electricity Regulation (COM(2016) 861 final/2).
[38] Article 9(1) of the 2009 Gas Directive (2009/73/EC).
[39] Article 9(1) of the 2009 Gas Directive (2009/73/EC).
[40] Article 2(21) and 15(1) of the 2009 Gas Directive (2009/73/EC). The exemption for “production operation” in the definition on “storage facilities” in article 2(9) does not apply. According to the European Commission, this exemption may only be invoked when the facility is exclusively used for smoothing irregularities associated with the specific process of production fields or areas.[153]

6 Developments in Electricity Markets Design

Key Findings

- The Clean Energy for all Europeans Package contains proposals to expose generators of electricity from renewable sources to market signals in order to stimulate the deployment of, amongst others, energy storage
- Electricity price control mechanisms, which may hinder power-to-gas and other energy storage technologies to make profit through (cross-sectoral) price arbitrage, need to be limited
- Involuntary electricity generation curtailments which may hinder the deployment of energy storage and conversion technologies such as power-to-gas need to be minimized
- New balancing market rules are intended to integrate energy storage into ancillary markets for the provision of frequency reserve services

6.1 Introduction

As it stands today, a profitable business case of power-to-gas requires the aggregation of multiple income streams.[49] Besides arbitraging on price spreads within electricity markets, or between electricity and gas markets, a dynamic operation of a fast ramping electrolyser also allows power-to-gas facilities to participate in frequency ancillary markets.[50] The aim of this Chapter is to provide an overview of certain rules and mechanisms in the European electricity market design which have a potentially direct or indirect effect on the operation and business case of energy storage and power-to-gas. The focus thereby will be on the rules proposed in the Recast Electricity Directive and Regulation which aim to expose generators of electricity from renewable sources to market signals in order to stimulate the deployment of, amongst others, energy storage. In the recital of the Recast Electricity Regulation it is stated: "*[d]erogations to fundamental market principles such as balancing responsibility, market-based dispatch, or curtailment and redispatch reduce flexibility signals and act as barriers to the development of solutions such as storage, demand response or aggregation.*"[41]

The intention of this Chapter is not, however, to provide an extensive analysis of the impact of electricity market rules on energy storage or power-to-gas. Such an analysis has already been provided by other projects and reports, *see* [9][39][37] [43]. Furthermore, research on power-to-gas in the electricity context will already be executed by Workpackage 6 of the STORE&GO project. Instead, three innovations in the electricity market design under the Clean Energy for All Europeans have been selected which have a direct link to the power-to-gas business case: abolishment of price control mechanisms (section 6.2), minimisation of curtailment (section 6.3), and the rules on the balancing market for frequency ancillary services (section 6.4).

6.2 Limitations to Electricity Price Control Mechanisms

Price arbitrage is a potentially important value stream for energy storage operators.[52] By charging in times of off-peak prices and discharging when prices peak, operators can exploit temporal price spreads in or between energy markets. Contrary to other energy storage technologies, power-to-gas is not limited to electricity markets for the sale of the energy stored, but

[41] Recital 11 of the Recast Electricity Directive (COM(2016) 864 final/2).

can equally offer its output in gas or fuel markets. This allows power-to-gas operators not only to exploit spreads in peak and off-peak prices of electricity, but also between electricity and gas prices.[53] In both cases, however, the value generated by arbitrage can be negatively affected by policies which bridle the free floating of electricity prices.

A condition for arbitrage is that energy prices are free to adapt to intra-day or seasonal swings in demand and supply.[38] To put it simply, the larger the price spread, the larger the profit. Price control mechanisms form a barrier to price arbitrage opportunities by preventing the market to come to an equilibrium price in times of excess of scarcity of electricity. Regulatory price floors thereby deny power-to-gas operators from profiting of close-to-zero or even negative electricity prices. Similarly, price caps, aimed at the protection of consumers from price volatility, deny operators the opportunity to bank on scarcity prices. Both price floors and price caps are, therefore, regarded as significantly affecting the storage business case. It is argued that price control mechanisms will be unnecessary when flexibility providers such as storage are allowed to fully participate in wholesale and balancing markets.[39] Provided that the market is sufficiently liquid, flexibility providers will have a stabilising effect on energy prices by enhancing (short-term) demand elasticity.

The market distorting effect of price caps has also been recognised by the European Commission as an obstacle for the economic viability of flexible resources. In the recital section of the Recast Electricity Regulation it is stated that: *"effective scarcity pricing will encourage market participants to be available when the market most needs it and ensures that they can recover their costs in the wholesale market."*[42] In order to promote free price formation, the proposed Regulation prescribes clear limitations for Member States on price restrictions.[43] Price caps on the wholesale electricity price will be no longer allowed, unless set at the value of lost load.[44] Similarly, floor prices higher than minus €2000 will be required to be abolished.

6.3 Incentivising Power-to-Gas by Minimising Curtailment

Curtailment can be defined as the reduction of output of a electricity generation unit to a level which is lower than the potential maximum output at a certain moment.[54] Although curtailment of output results in renewable generation potential going to waste, this may nevertheless be necessary at times that the unlimited injection of electricity in the network is not possible due to capacity constraints in the network.[55] As an alternative to output curtailment, power-to-gas can store the otherwise curtailed electricity for later use, or put the energy to use as hydrogen or SNG elsewhere in the energy system. As power-to-gas thereby prevents renewable energy from going to waste, this can be considered a favourable option over curtailment. Incentives in support of curtailment should, therefore, be minimised or abolished. This has also been recognised by European Commission: *"curtailment should be a measure of last resort which is limited to situations in which no market-based resources are available (including storage and demand response), and only subject to transparent rules."* [56]

Currently, as a side effect of feed-in tariffs and priority dispatch, renewable generators lack incentives to voluntarily reduce their output during times of low demand.[58][38] Priority dispatch and priority access may even lead to situation where generators continue to inject electricity into the network when prices are negative. [18][58] When this injection of electricity in times of low demand threatens the balance and integrity of the network, system operators have the choice to

[42] Recital 10 of the Recast Electricity Regulation (COM(2016) 861 final/2).
[43] Article 9 of the Recast Electricity Regulation (COM(2016) 861 final/2).
[44] "Value of lost load" means an estimation in €/MWh of the maximum electricity price that customers are willing to pay to avoid an outage.

either upgrade the network in order to facilitate peak-flows, or to curtail the output of generators in return for compensation.[55][54] Such compensation, also known as curtailment payments, may disincentive generators to consider alternatives such as power-to-gas and other energy storage technologies.[38][40]

The Recast Electricity Directive requires that curtailment of electricity from renewable sources or high-efficiency cogeneration should be minimised.[45] If curtailment is nevertheless necessary, generation or demand units may submit an offer to be compensated for voluntary curtailment. Importantly, involuntary curtailment at the discretion of the system operator may only be taken when all market-based resources are exhausted and no alternative exist.[46] Explicitly mentioned as market-based resources are energy storage and demand response measures. As such, system operators are not allowed to require and pay generators to involuntarily curtail their output when operators of energy storage installations, including power-to-gas, can provide an alternative form of flexibility.

6.4 Power-to-Gas Providing Frequency Reserve as Ancillary Service

Part of the task of a transmission system operator is to ensure the reliable operation of the electricity grid for the transportation of electricity.[47] In order maintain the electricity grid in balance, system operators make us of ancillary services provided by system users. Ancillary services are defined in the 2009 Electricity Directive as those services necessary for the reliable operation of a transmission or distribution grid.[48] Such services are preformed over different timeframes and include black start capability (the ability to restart a grid following a blackout), voltage control, and frequency reserve.[141] Frequency reserves assist the system operator in containing the grid frequency at 50Hz (for continental Europe) after an imbalance occurs, or help to restore the frequency to this required level. When the frequency drops below 50 Hz, the system operator will request the frequency reserve provider to regulate upwards by increasing its output or lowering its demand. When the frequency rises above 50 Hz, reserve providers need to perform down-regulation by lowering output or increasing demand. Frequency reserve is subdivided in primary-, secondary-, and tertiary frequency reserves depending on the required response time. As illustrated in figure 6-1 below, for primary reserve the response time lies within the sub-seconds to seconds time frame, for secondary reserve seconds to minutes, and for tertiary reserve minutes to hours. The dynamic operation of fast up- and down-ramping electrolysers allow power-to-gas facilities to offer frequency reserve capacity within all required timeframes.[10]

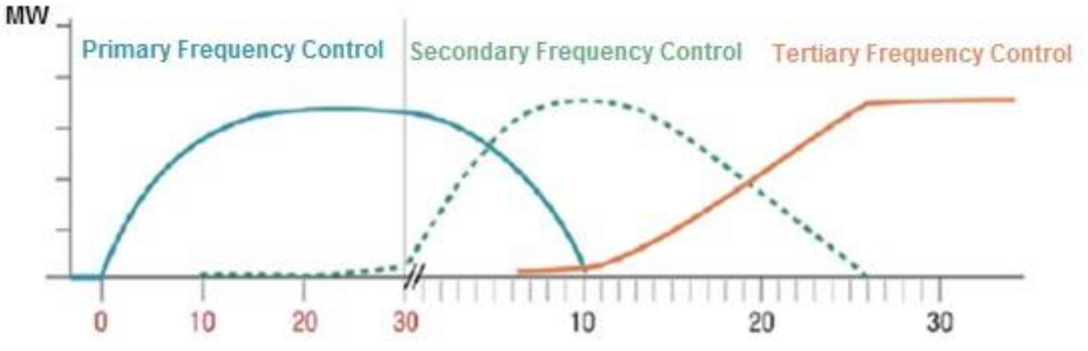

Figure 6-1: Timeframe Primary-, Secondary-, and Tertiary Frequency Reserves (image by [57])

[45] Article 12 (4)(b) of the Recast Electricity Regulation (COM(2016) 861 final/2).
[46] Article 12 of the Recast Electricity Regulation (COM(2016) 861 final/2).
[47] Article 12(a) of the 2009 Electricity Directive (2009/72/EC).
[48] Article 2(17) of the 2009 Electricity Directive (2009/72/EC).

As frequency reserves play an important role in maintaining the reliable operation of the grid, system operators are responsible for ensuring the availability thereof.[49] This does not, however, mean that system operators may provide such services to itself. As will be discussed under the next paragraph, a system operators is required to procure such services from flexible generators and flexibility providers in the market. This is also reflected in the proposed Article 54 of the Recast Electricity Directive. Not only does this article limit the ownership and control of transmission system operators over storage facilities to situations where the market is absent or passive, it also states that these operators *"shall not own directly or indirectly control assets that provide ancillary services"*. Although similar derogations are allowed to this basic rule as for the ownership of storage facilities (*see* section 5.3.2), this is limited to assets providing non-frequency ancillary services.[50] Accordingly, even when a transmission system operator takes control over an energy storage facility in derogation of the basic rule that this should not be allowed, the system operator is still denied the possibility to offer frequency ancillary services to itself.

The use of reserves by a system operator for maintaining the frequency of the grid at a predefined level (50 Hz) is called "balancing".[51] In the past, the provision of such balancing services by generators to the system operator was often mandatory. A recent survey by ENTSO-E on ancillary services shows a clear trend towards more flexible and market-based procurement mechanisms such as bilateral contracts, tendering, and spot-markets.[52] The survey also reveals that the national rules on ancillary services are still of a heterogonous nature. As European electricity markets become increasingly integrated, the soon to be adopted European guideline on electricity balancing aims to harmonise these heterogeneous rules on balancing in order to promote cross-border balancing.[59][53] According to ENTSO-E, the *guideline creates a level-playing field for all potential providers of balancing Services, including demand side response, energy storage and intermittent sources.* [60]

The Recast Electricity Regulation and the Guideline on electricity balancing require system operators to procure balancing services from generation units and other flexible service providers on the balancing market.[54] Importantly, the Recast Electricity Regulation explicitly requires that such balancing markets are organised in such a way to ensure effective non-discriminatory participation of market participants such as demand response and energy storage while taking into account their different technical capacities.[55] In order to stimulate the participation of technologies which can, or choose to, only provide up- or downward regulation, the procurement of upward balancing capacity and downward balancing capacity need to be carried out separately.[56]

In conclusion, recent legislative developments explicitly stimulate the participation of energy storage technologies, including power-to-gas, in balancing markets for the provision of frequency reserve ancillary services.

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[49] Article 12(d) of the 2009 Electricity Directive (2009/72/EC).
[50] Article 2(38) of the Recast Electricity Directive defines "non-frequency ancillary service" as a service used by a transmission or distribution system operator for steady state voltage control, fast reactive current injections, inertia and black start capability.
[51] Article 2(i) of the Recast Electricity Regulation (COM(2016) 861 final/2).
[52] Survey of the past five years are available on the website of ENTSO-E: https://www.entsoe.eu/publications/market-reports/ancillary-services-survey/Pages/default.aspx.
[53] Article 1 of the Draft Commission Guideline on Balancing. The Guidelines has been approved by the Member States in comitology in March 2017. Although adopted as a guideline under the 2009 Electricity Regulation, the guideline has a similar legally binding status as Network Codes adopted through a comitology process.
[54] Article 5 of the Recast Electricity Directive (COM(2016) 864 final/2) and Title III of the Guideline on Electricity Balancing.
[55] Article 5(2) of the Recast Electricity Directive (COM(2016) 864 final/2).
[56] Article 5(9) of the Recast Electricity Directive (COM(2016) 864 final/2).

7 Substitute Natural Gas under EU Gas Legislation

Key Findings

- Member States have the discretion to opt for a specific authorisation regime for the construction and operation of a facility which produces gas
- If opted for, the system of authorisation needs to be based on transparent, objective, and non-discriminatory criteria
- Access to the natural gas grid for the injection of SNG is conditioned by technical and safety rules, including gas quality standards
- Gas quality standards, including the Wobbe Index, are of a heterogeneous nature due to the composition of locally produced or imported gas to which end-use appliances have been adapted
- Recently adopted European standards concerning high calorific gas and biomethane prescribe harmonised gas quality parameters
- Gas quality harmonisation efforts have not, however, resulted in a consensus on the Wobbe Index or hydrogen limit

7.1 Introduction

This Chapter will focus on European legislation concerning the production (section 7.2) and grid injection (section 7.3) of natural gas which are also relevant to SNG. At the centre of the discussions in this Chapter will be the 2009 Gas Directive. The applicability of this Directive, and the rules contained therein on natural gas, to hydrogen and SNG has already been discussed in section 4.2 of this Deliverable.

7.2 National Authorisations for the Production of Gas

The 2009 Gas Directive contains only limited guidance with regard to national authorisation requirements for the production of gas. This is because conditions for granting authorisations for the production of hydrocarbons such as natural gas are already covered by the Hydrocarbons Directive (94/22/EC). As, however, SNG is not a hydrocarbon resource located in the subsoil of which the production is tied to a fixed location, the Hydrocarbons Directive does not apply thereto.

Contrary to the 2009 Electricity Directive which also covers the generation, or production, of electricity, the scope of the 2009 Gas Directive is limited to the establishment of common rules for downstream activities such as transmission, storage, and supply.[57] However, it has been suggested that the rules contained in the 2009 Gas Directive on authorisation procedures for gas facilities also apply to biogas facilities.[22] Possibly, these rules would then also apply to power-to-gas installations which produce SNG. Looking at the substance of the rules in the 2009 Gas Directive regarding authorisation procedures, Article 4 does not impose an obligation on Member States to establish a specific authorisation procedure (e.g. license, permit, concession, or approval) for the construction or operation of gas facilities.[58] Therefore, Member States have the discretion to choose whether they want to expand their authorisation procedures beyond the application of environmental, safety, and spatial planning rules. However, where Member States do opt for specific authorisation requirements for gas facilities, Article 4 of the 2009 Gas Directive

[57] Article 1 of both the 2009 Electricity- and Gas Directive (2009/72/EC and 2009/72/EC).
[58] Article 4(1) of the 2009 Gas Directive (2009/73/EC).

requires that the system of authorisation shall be based on transparent, objective, and non-discriminatory criteria.[59]

Another important condition prescribed by European energy law is the previously discussed unbundling rule. This rule prohibits an undertaking owning a transmission and/or distribution system to also exercise, directly or indirectly, control over a gas production undertaking (*see* section 5.2).

In short, Member States do not have to follow the competitive authorisation procedures prescribed under the Hydrocarbons Directive for the production of SNG. The 2009 Gas Directive does not oblige Member States to impose an authorisation procedure for the construction and operation of power-to-gas plants. But where they do, the system of authorisation needs to be based on transparent, objective, and non-discriminatory criteria.

7.3 Grid Injection of Substitute Natural Gas

Although not yet fully operational, the three STORE&GO pilot sites are expected to produce SNG containing at least 90 percent methane (CH_4) and limited traces of carbon dioxide (CO_2), and hydrogen (H_2). The extent that such gases may be injected into the natural gas grid will depend primarily on technical and safety rules, such as gas quality parameters. This section will, therefore, discuss how technical and safety rules condition access to the natural gas grid (subsection 7.3.1), the development and implications of heterogeneous national gas quality standards (subsection 7.3.2), and recent efforts to harmonise such standards at the EU level. An assessment of the gas quality parameters in Germany, Italy and Switzerland will be presented in Deliverable 7.3 of the STORE&GO project, of which the focus is on national legislation.

7.3.1 Non-discriminatory Access to the Gas Grid and Technical Safety Rules

The 2009 Gas Directive prohibits system operators from discriminating between entities which want to inject gas into the natural gas system and which can be considered to be equal.[62][60] The so called “third party access requirement” requires Member States to ensure that all system users are awarded an equal right of access to the natural gas system.[61] According to the European Court of Justice, the term “access” is linked to the supply of energy, including *inter alia* the quality, regularity and cost of the service.[63][62] The third party access requirement thus applies to the *use* of the system in order to have gas transported from the producer to the customer, not the physical connection.[22] The third party access requirement does not, however, prohibit system operators or national legislators to differentiate between classes of system users based on objective criteria.[62] Such objective criteria can be found in technical safety criteria which are aimed at ensuring the integrity of the gas system, including gas quality standards.[63] Accordingly, entities which request access to the gas system but do not comply with the technical safety rules, can be refused access to the system.[64] With regard to the injection of gases other than natural gas into

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[59] Article 4(2) of the 2009 Gas Directive (2009/73/EC).
[60] Article 13(1)(b) and 32(1) of the 2009 Gas Directive (2009/73/EC).
[61] Article 32 of the 2009 Gas Directive (2009/73/EC) for transmission and distribution networks and Article 33 for storage facilities.
[62] European Court of Justice, case-239/07, *Julius Sabatauskas and Others*, [2008], ECR II-7253.
[63] In the 2009 Gas Regulation, the term “system integrity” is defined as *“any situation in respect of a transmission network including necessary transmission facilities in which the pressure and the quality of the natural gas remain within the minimum and maximum limits laid down by the transmission system operator, so that the transmission of natural gas is guaranteed from a technical standpoint.*” Article 2(19) of the 2009 Gas Regulation No 715/2009. The term “system” is defined under article 2(13) of the 2009 Gas Directive as “system” means any transmission networks, distribution networks, LNG facilities and/or storage facilities owned and/or operated by a natural gas undertaking”.

the gas grid, including SNG, the condition of compliance with technical and safety rules is explicitly prescribed under Recital 41 of the 2009 Gas Directive:

> *"Member States should ensure that, taking into account the necessary quality requirements, biogas and gas from biomass or other types of gas are granted non-discriminatory access to the gas system, provided such access is permanently compatible with the relevant technical rules and safety standards".*

In conclusion, compliance with gas quality standards is an important prerequisite for being allowed to inject SNG into the gas grid.

7.3.2 Heterogeneity of National Gas Quality Standards

A gas quality standard prescribes the maximum and minimum acceptable limits of individual parameters and components of a gas. In absence of a legislatively harmonised gas quality standard at the European level, Member States have adopted their own gas quality standards in the past. Gas quality standards are introduced by Member States to guarantee the technical and safe transportation of gas through the gas infrastructure, and to ensure the safe and proper functioning of household, commercial, and industrial end-use appliances.[72] These national standards where adopted in conformity with the composition of locally produced and/or imported gas. Every natural gas reservoir has its specific composition and thus gas quality. Together with the existence of fragmented national gas markets before the introduction of the internal energy market, these different national circumstances have resulted in heterogeneous gas quality standards among Member States. [64][65]

Member States, in general, are cautious in adopting broad gas quality standards. A too broad gas quality bandwidth may have a negative impact on the safety, efficiency, and emissions of end-use appliances. [66] For example, variations in the Wobbe Index or hydrogen content of a gas have a potential impact on the operation of finely tuned gas turbines for optimal power production and may result in costly adaptations.[67][64] Another example is that relatively high levels of hydrogen in a gas, 10 percent or higher, may lead to the embrittlement of metals such as steel.[36] Accordingly, the technical, safe, and efficient operation of the gas grid and end-use appliances pleads in favour of narrow gas quality standards which only allow access to the gas network for gases which comply with the prescribed parameters.

Pleading in favour of a wide bandwidth for gas quality parameters is the increasing diversification of gas supply within the EU in order to maintain a sufficient level of security of gas supply. The downturn in domestic natural gas production has led to an increase of imports in order to satisfy demand.[68] This import will involve increased volumes of gas with different gas quality standards flowing into the EU from third countries. Another recent development which pleads in favour of wide broad gas quality parameters is the increased production of alternative, more sustainable, gases such as (upgraded) biogas, hydrogen produced from renewable sources, and SNG.[65] A too narrow gas quality range may exclude these gases from entering the EU gas market or being traded across borders. Such a barrier to the distribution of gases from renewable energy sources contradicts with decarbonisation efforts under EU climate and environmental policies.

The discretion of Member States to determine national gas quality standards in absence of harmonisation is not unlimited. In its guide related to the provision of information of technical standards and regulations the Commission states: "*to be admissible as an exception to the*

[64] The Wobbe Index, often indicated as the energy content in MJ per m^3 (NTP), is used to compare the combustion energy output of gases with different chemical compositions.

[65] According to the European Biogas Association, the number of biomethane plants for the production and upgrading of biogas to natural gas quality is increasing since 2011 with 25% per annum.[147]

fundamental freedoms of the internal market in a non-harmonised area, a national restriction must, on the basis of (…) case law comply with the principles of non-discrimination, necessity, and proportionality).'[69] It follows from this that, under certain circumstances, a restrictive gas quality standard which leads to the denial of access of a gas to the network, or high costs for a producer to bring a gas into compliance, may be unnecessary or disproportionate. Such circumstances may be that there exists empirical evidence that broader standards are possible, or that the denial of access or costs for producers are disproportionate to the costs of adapting end-use appliances.[64]

As heterogeneous gas quality standards may hinder cross-border trade in gas, and the access to the grid of gases from renewable sources, efforts have been made to develop harmonised standards at the EU level. These efforts, and the results thereof, are discussed in the following subsection.

7.3.3 Harmonisation Efforts Concerning Gas Quality Standards

Interoperability of national gas systems is becoming increasingly important as more gas will be imported into the EU. In 2016, the natural gas import dependency of all 28 EU Member States was 70,4 percent.[68] The majority of this imported gas has to cross at least one internal border within the EU in order to arrive at the location of consumption.[65] In order to develop harmonised gas quality standards which enhance the interoperability of gas systems, the European Commission has mandated the European Committee for Standardization (CEN), of which Switzerland is a member, to develop a standard for both high caloric gases and biomethane. Both these standards developed will be discussed below.

Importantly, Member States are not obligated to comply with CEN standards, unless the standard has been made binding by the inclusion of a reference thereto in a legislative instrument.[70] This is apparent from the definition of the term "standard" in the EU Regulation on European Standardisation (Regulation (EU) No 1025/2012).[66] Nevertheless, through the Internal Regulations of the CEN, its Members have committed themselves to implement European Standards (EN) at the national level by awarding those the status of a national standard and by withdrawal of any conflicting standards.[70]

7.3.3.1 European Standard on the Quality of High Calorific Gases - Mandate M/400

The first mandate to be discussed, known as M/400, stems from 2007 and requests the CEN to draw up standards that define the minimum range of gas quality parameters for so called "H-gases".[71] H-gases are those gases which at 15° Celsius and 1013,25 mbar have a Gross Wobbe Index between 45,7 and 54,7 MJ/m^3.[149] The mandate requires the CEN to develop standards for the following gas quality parameters:

- Gross Wobbe index
- Relative density
- Oxygen
- Total sulphur; hydrogen sulphide + carbonyl sulphide
- Mercaptans
- Carbon Dioxide
- Water dew point
- Hydrocarbon dew point

Notably, hydrogen was explicitly excluded from the scope of the work of CEN under M/400 as, according to the European Commission: *"current gas flows do not contain hydrogen and it is not an issue yet in the gas market, i.e. production, transport or appliance-use."* However, the Commission mentions in the text of mandate M/400 that the proposed set of parameters could be re-evaluated when synthetic gases are anticipated to be introduced on the European gas market.

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[66] Article 2(1) of the Regulation on European Standardisation (Regulation (EU) No 1025/2012) defines a standard as: *"'standard' means a technical specification, adopted by a recognised standardisation body, for repeated or continuous application, with which compliance is not compulsory (…)".*

The mandate instructs CEN to aim for gas quality standards *“that are the broadest possible within reasonable costs”*. This instruction refers to the earlier mentioned challenge to find a balance between the safe operation of the system and connected appliances with the enhancement of the free flow of gases from various sources in favour of trade, security of supply, and the environment. In order to gain sufficient insight into the potential costs and benefits of harmonising gas quality standards within the EU, the European Commission commissioned a report which issued in 2012.[72] The identified risks and benefits by this study are summarised in Table 7-1 below. As the mandate instructs to take account of the full gas chain from production to consumption, the costs assessment had to include the costs for bringing existing and new appliances into compliance with both narrow and wide gas quality bandwidths and the safety conditions under the Gas Appliances Directive (2009/142/EC).[73]

Benefits	**Costs and risks**
Increased competition in the internal gas market due to increased opportunities for cross-border trade and market integration;	Increased costs for producers and shipper for bringing off-spec gas in compliance with quality standard (de- or enrichment);
Increased competitiveness in the market for domestic gas appliances which is currently segmented due to different standards;	Increased costs for consumers when existing appliances need to be adapted;
Increased diversification of supply routes leading to more (cost-)efficient transportation of gas;	Inefficiencies when gas quality sensitive appliances are fed whit varying gas qualities.
Enhance security of supply due increased diversification of supply.	

Table 7-1: Costs and Benefits of Gas Quality Harmonisation

An argument not mentioned in the report, but certainly relevant for sustainable gases such as SNG, is the contribution of these gases to the decarbonisation of gas consuming applications and sectors. A sufficiently wide and harmonised gas quality standard may promote the market introduction and trade of these gases.

The drafting and preparation of a European standard for the specification of the quality of high calorific gases under mandate M/400 has been executed by Technical Committee CEN/TC 234 on “gas infrastructure”. The resulting standard “EN16726” specifies *“gas quality characteristics, parameters and their limits, for gases classified as group H that are to be transmitted, injected into and from storages, distributed and utilized.’*[74] The standard was approved in September 2015 and had to be transposed by CEN members before June 2016. Initially, the European Commission had the intention to make compliance with EN 16726 compulsory by including a reference to this standard in the Network Code on interoperability and data exchange rules. However, as the CEN members were unable to find consensus on a common Wobbe Index, the Commission decided to stall the introduction of legally binding provisions in conjunction with standard EN 16726 until an agreement could be reached.[75] This lack of consensus was caused by conflicting legislation in several CEN Member States and limited knowledge on the effect of a broad Wobbe Index Range on the integrity, efficiency, and safe use of appliances.[74][67]

H-gas quality parameter on which consensus was reached are as followed:

[67] *See* Annex D to EN 16726:2015 for more background for not including a Wobbe Index Range into the standard.

Parameter	Unit	Minimum limit value	Maximum limit value
Relative density	-	0.555	0.700
Total sulfur without (with) odourant	Mg/m^3	-	20 (30)
Hydrogen sulphide + carbonyl sulphide	Mg/m^3	-	5
Mercaptan sulfur	Mg/m^3	-	6
Oxygen	Mol/mol	-	10 ppm to 1%
Carbon dioxide	Mol/mol	-	2.5% to 4%
Hydrocarbon dewpoint	°C (up to 70 bar)	-	-2
Water dew point	°C (at 70 bar)	-	-8
Methane	-	65	-

Table 7-2: Gas Quality Parameter in EN 16726:2015

As mentioned, a parameter for admissible concentrations of hydrogen in the natural gas system was excluded from mandate M/400. However, as SNG produced through power-to-gas may still contain limited volumes of hydrogen, a EU wide standard for hydrogen content may, nevertheless, be desirable. Adding to the urgency to harmonise hydrogen limits within the EU is the prospect of pure hydrogen from renewable sources being added to the natural gas stream. To this regard, the European Commission has recently remarked in an informal staff working document on energy storage:

> *"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 and the gas networks".*[35]

Being aware of these developments, but unable to find consensus on a definite and uniform parameter on the volume of hydrogen in natural gas system, the Technical Committee and CEN members have adopted an informative Annex E on hydrogen to standard EN 16726. This Annex refers to a study by the European Gas Research Group (GERG) which shows that an admixture of up to 10 percent by volume of hydrogen is safe and technically possible in certain parts of the natural gas system.[36] Annex E recommends a case by case analysis depending on the local (storage) infrastructure and possible end-use. With regard to gas turbines, the Annex states that minor modifications to currently installed turbines could result in an acceptable hydrogen concentration volume of 5 percent. For new or upgraded turbines, the concentration volume could be up to 15 percent according to Annex E.

On a final note, it needs to be stressed that certain parameters, and the conditions in which they apply, are further specified under the Annexes to EN 16726. It lies beyond the scope of this Deliverable to provide an integral analysis of the standard as a whole. Similarly, reservations made by several Member States to certain parameters because of deviating national legislation (so called "A-deviations) can be found in the standard itself under Annex G.

7.3.3.2 European Standard on the Quality of Biomethane - Mandate M475

As explained is Chapter 2, power-to-gas can also be deployed for biogas upgrading in order to bring the methane content of biogas to a similar level as that of natural gas. As will be elaborated on below, such upgraded biogas is defined as biomethane. Although this particular power-to-gas concept is not deployed within the STORE&GO project, this process may nevertheless become widely applied in the future as an alternative to conventional biogas upgrading processes, such as CO_2 scrubbers. For this reason, this subsection will briefly cover mandate M/475 concerning a European standard on the quality of biomethane, which was delegated to the CEN by the European Commission.[76] In fulfilment of its mandate, CEN Technical Committee CEN/TC 408 has developed two standards:

- EN 16723-1: Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network — Part 1: Specifications for biomethane injection in the natural gas network (approved in September 2016; national implementation before June 2017);[144]
- EN 16723-2: Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network — Part 2: Automotive fuel specifications (approved in April 2017; national implementation before January 2018).[77]

According to the text of M/475, biomethane can be either produced through biological processes based on biogas upgrading, or by thermochemical processes through the catalytic treatment of synthesis gas downstream of biomass gasification processes. This description of biomethane production processes has been translated in the subsequent CEN standards into the following definition of biomethane, related gases and processes:[68]

> *'Biomethane': gas comprising principally methane, obtained from either upgrading of biogas or methanation of bio-syngas*
>
> *'Biogas': gas, comprising principally methane and carbon dioxide, obtained from the anaerobic digestion of biomass*
>
> *'Bio-syngas': gas, comprising principally carbon monoxide and hydrogen, obtained from gasification of biomass*
>
> *'Upgrading of biogas': removal of carbon dioxide and contaminants from biogas*

It follows that when power-to-gas is deployed for the upgrading of biogas by removing carbon dioxide through the hydrogenation thereof, the output gas fits the definition of biomethane under the respective standards.

As the work under M/475 was not intended to overlap with that under M/400, standards EN 16723-1 and 2 need to refrain from defining any parameters or substances already covered under EN 16726. The instruction was only to specify additional or more strict limits for parameters or substances unique to biomethane. Table 7-3 and Table 7-4 below provide an overview of the included parameters in both EN 16723-1 and 2 respectively.

[68] *See* section 3 "Terms and Definitions" of CEN EN 16723-1 and EN 16723-2.

Parameter	Unit	Minimum limit value	Maximum limit value
Total volatile silicon (as Si)	mgSi/m^3	-	0.3 (pure) to 1 (diluted)
Compressor oil		Free from impurities	
Dust impurities		Free from impurities	
Carbon monoxide (CO)	% mol	-	0.1
Ammonia (CH3)	Mg/m^3	-	10
Amine	Mg/m^3	-	10

Table 7-3: Biomethane Parameters EN 16723-1

Parameter	Unit	Minimum limit value	Maximum limit value
Total volatile silicon (as Si)	mgSi/m^3	-	0.1 or 0.5
Hydrogen	% mol/mol	-	2
Hydrocarbon dewpoint	°C (up to 70 bar)	-	-2 (as in EN 16726)
Hydrogen sulphide + carbonyl sulphide	Mg/m^3	-	5
Oxygen	% Mol/mol	-	1
Compressor oil		Minimal	
Dust impurities		Minimal	
Carbon monoxide (CO)	% mol	-	0.1
Ammonia (CH3)	Mg/m^3	-	10
Amine	Mg/m^3	-	10

Table 7-4: Biomethane Parameters EN 16723-2

The hydrogen content in EN 16723-2 on automotive fuel specification has been set at 2 percent as this the limit value for hydrogen in steel tanks in natural gas vehicles as specified under United Nations Economic Commission for Europe Regulation No. 110.[69] With regard to the total sulphur content, earlier discussed standard EN 16726 on gas quality parameters of H-group gases sets the value at 20 mg/Sm^3 for non-odorised gas and 30 mg/Sm^3 for odorized gas, as odorisation increases the sulphur content in a gas. Such odorisation generally occurs at the distribution level. Annex B to EN-16732-2 explains, however, that the automotive industry cannot accept sulphur contents above 10 mg/Sm^3 because of the sensitivity of the exhaust catalyst. As a consequence, the transport of biomethane over the natural gas grid could result in a gas quality which is unfit for consumption in transport.

[69] *See* Annex A.2 to CEN EN 16723-1.

8 Substitute Natural Gas in the Renewable Energy Context

Key Findings

- To the extent that SNG is produced from electrical energy generated from a renewable source, SNG could be considered to be a “renewable gas” or “gas from renewable source”, thereby falling under the scope of the Renewable Energy Directive
- The 2009 and/or Recast Renewable Energy Directives do not contain conditions which limit the choice for a carbon source for the production of SNG to either a fossil-, biogenic-, or ambient carbon source
- It is unlikely that the sustainability criteria also apply to SNG when only the carbon source originates from biomass but not the energy content
- The Recast Renewable Energy Directive introduces the obligation for Member States to issue guarantees of origin for gases from a renewable source. Issues remain, however, with regard to the lifetime of such documents and the need for guidance when energy is converted from one energy carrier to another
- The consumption of SNG cannot yet be fully counted towards national mandatory targets concerning the share of renewable energy in gross final energy consumption
- Under the Recast Renewable Energy Directive, the perceived contribution of gases from a non-biological renewable origin, including SNG, towards a fuel supplier’s blending obligation is limited
- Fuel suppliers may not use guarantees of origin to increase the share of renewable energy in fuels which have electricity as their feedstock

8.1 Introduction

Chapter 3 already introduced the obligation for EU Member States to comply with a mandatory national target concerning the share of energy from renewable sources in gross final *consumption* in 2020, including a sector specific target for the share of renewable energy in transportation of 10 percent.[70] For the 2020-2030 era, the Council of the European Union has adopted a Union-wide binding target of 27 percent by 2030, which has been included in the Recast Renewable Energy Directive. In order to accelerate the shift from fossil energy sources to renewable sources, the EU legal framework provides Member States with multiple tools and mechanisms to achieve this transition.

The majority of these mechanisms and related rules can be found in the Renewable Energy Directive. In order to promote the use of energy from renewable sources, the Directive lays down rules on *inter alia* guarantees of origin, support schemes, administrative procedures, and sustainability criteria for biofuels and bio liquids.[71] All these rules are intended to contribute to a favourable climate for investments in renewable energy. The relevance of the Renewable Energy Directive and its content for power-to-gas becomes apparent from a reading of Recital 48 of the Recast Renewable Energy Directive:

[70] For example, Annex I Part A to the 2009 Renewable Energy Directive states that the national mandatory targets for Germany and Italy in 2020 are 18 percent and 17 percent respectively.
[71] Article 1 of the 2009 Renewable Energy Directive (2009/28/EC).

> *"There is a need to support the integration of energy from renewable sources into the transmission and distribution grid and the use of energy storage systems for integrated variable production of energy from renewable sources, in particular as regards the rules regulating dispatch and access to the grid. Directive [Electricity Market Design] lays down the framework for the integration of electricity from renewable energy sources. However, this framework does not include provisions on the integration of gas from renewable energy sources into the gas grid. It is therefore necessary to keep them in this Directive."*[72]

This Chapter, in section 8.2, will first explore to what extent SNG is covered under the scope of the 2009 and Recast Renewable Energy Directive. The following section 8.3 will assess to what extent the choice of carbon for the production of SNG is conditioned under the Renewable energy Directive. Subsequent section 8.4 reviews the eligibility of SNG from renewable sources to guarantees of origin. Final section 8.5 will address certain measures under the 2009 and Recast Renewable Energy Directives which may stimulate the consumption of SNG for different end-uses. Although also covered under the Renewable Energy Directive, eligibility for developers/operators of power-to-gas plants to support schemes and simplified administrative procedures are discussed elsewhere, under section 9.2 and section 10.4 respectively.

8.2 Substitute Natural Gas as a Gas of a Renewable Source

Before addressing the different topics covered under the Renewable Energy Directive which are relevant to SNG, this section will assess to what extent this Directive applies to this synthetic gas. Contrary to natural gas or biogas, SNG cannot be considered to be a primary renewable source. It is rather, similar to electricity, a secondary energy carrier of which the renewable character depends on the source of its energy content. What qualifies as energy from renewable sources is defined under the Renewable Energy Directive as:

> Article 2(a) 2009 RES Directive:
>
> *'energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.*
>
> Article 2(a) Recast RES Directive:
>
> *'energy from renewable sources' means energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient heat, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.*

It follows from these definitions that SNG can be considered as "energy from renewable sources" to the extent that the electricity which is fed into the electrolyser has been generated from one of the listed non-fossil energy sources.

Besides using the generic term "energy from renewable sources", the 2009 and Recast Renewable Energy Directives include references to both "gas from renewable sources" and "renewable gas". For example:

> *Recital 47 of the Recast renewable Energy Directive: "Guarantees of origin, (…), should be extended to cover renewable gas." (…) It would also enable the creation of guarantees of origin for other renewable gases such as hydrogen."*

[72] The term "Electricity Market Design" refers to the Recast Electricity Directive COM(2016) 864 final/2 and Regulation (COM(2016) 861 final/2).

> *Article 20 (1) of the Recast renewable Energy Directive: "Where relevant, Member States shall assess the need to extend existing gas network infrastructure to facilitate the integration of gas from renewable energy sources."*
>
> *Article 20(2) of the Recast renewable Energy Directive: "Member States shall also require transmission and distribution system operators to publish the connection tariffs to connect renewable gas sources based on transparent and non-discriminatory criteria."*

Although the terms "gas from renewable sources" and "renewable gas" are both not defined, they are broad enough to include other gases than biomass based gases under their scope.

In conclusion, SNG, to the extent that the electricity used for its production stems for a non-fossil renewable source, falls under the scope of the Renewable Energy Directive. As will be further explained under the next section, the renewable character of the produced SNG is not dependent on the source of carbon used for the methanation process.

8.3 Conditions to the source of Carbon under the Renewable Energy Directive

The central question in this section is whether the Renewable Energy Directive sets conditions for the origin of the carbon used for the production of synthetic gases such as SNG. This question is relevant as it has been demonstrated that the carbon balance of SNG is partially influenced by the choice for either a fossil, biogenic, or ambient carbon sources.[78] Within the STORE&GO project, the carbon sources used for the production of SNG are as follows:

Location	Type of Carbon Source	Provider
Germany – Falkenhagen	Biogenic	Sugar/bio-ethanol factory
Switzerland – Solothurn	Biogenic	Waste water treatment plant
Italy – Troia	Ambient	Ambient CO_2 adsorption process

Table 8-1: Carbon sources within the STORE&GO project

Fossil carbon is carbon released during the combustion or processing of fossil sources such as oil, coal and natural gas by power plants and industrial processes. Instead of being released into the atmosphere, this carbon can be captured through chemical or physical absorption methods at point source and be recycled in synthetic gases and liquids. This process in known as Carbon Capture and Utilisation (CCU).[73] Biogenic carbon is obtained from, amongst other processes, biogas upgrading, fermentation, or waste water treatment. Ambient carbon is extracted from the atmosphere through carbon capture filters which absorb the carbon from the atmosphere. As biogenic and ambient carbon are extracted from the atmosphere by biomass or filters, the usage thereof results in a more positive carbon balance then when using fossil carbon which was previously trapped in fossil sources.[78][79]

Coming to the central question posed at the beginning of this section, a reading of the definition on "energy of renewable sources", as provided in the previous section, does not reveal a condition with regard to the choice of carbon source. Similarly, there exists no other definition or provision in the 2009 or Recast Renewable Energy Directive which directly addresses the choice of carbon as a feedstock for synthetic gases. This seemingly unbiased approach is also reflected in an amendment in 2015 of the 2009 Renewable Energy Directive. This amendment introduced a

[73] Information by the European Commission Joint research Centre on CCU can be found at: http://s3 platform.jrc.ec.europa.eu/carbon-capture-and-utilization.

definition of *"renewable liquid and gaseous transport fuels of non-biological origin."*[74] These are defined as *"liquid or gaseous fuels other than biofuels whose energy content comes from renewable energy sources other than biomass, and which are used in transport"*.[75] SNG used in transport, and which has electricity generated from wind or solar as its feedstock, seems to be covered by this definition. As this definition only requires the *energy content* to be of a renewable source other than biomass, for example electricity from wind or solar, the definition seems unbiased with regard to the source of the carbon.

In conclusion, the 2009 and/or Recast Renewable Energy Directive contain no conditions with regard to the origin of the carbon used for the production of synthetic gases such as SNG.

8.3.1 Relevance of the Sustainability Criteria to Biogenic Carbon

Another question related to the choice of carbon source for the production of SNG, is whether the sustainability criteria for gases from biomass under the Renewable Energy Directive also apply to gases which only use the carbon released by biomass as a feedstock, and not the energy content. As displayed in Table 8-1 above, this is the case for the STORE&GO plant in Falkenhagen which receives its carbon from a sugar/bioethanol factory.

Article 17 of the 2009 Renewable Energy Directive contains the sustainability criteria for gaseous biofuels and bioliquids. Only those biofuels and bioliquids that comply with these criteria are eligible to:

a) be included in the calculation of the mandatory national targets;
b) be measured in compliance with national renewable energy obligation schemes;
c) to receive financial support for the *consumption* of biofuels and bioliquids.

The first sustainability criteria is that greenhouse emission savings from the use of biofuels and bioliquids produced by installations which came into operation after 5 October 2015 need to be at least 60 percent compared to their fossil comparator.[76] The second sustainability criteria is a collection of conditions concerning the origin and cultivation of the raw material used.

Importantly, the sustainability criteria only apply to substances produced from biomass.[77] Question is thus whether SNG which has carbon from biomass as a feedstock should be considered a gas produced from biomass. The term "biomass" is defined as *"the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances) (…) , as well as the biodegradable fraction of industrial and municipal waste"*.[78] It has been argued that carbon is by definition not the *"biodegradable fraction of products"* and should, therefore, not be considered biomass[80] Moreover, the carbon released during biomass digestion is considered to be an unwanted by-product which is removed during biogas upgrading and normally emitted into the atmosphere if not captured. When SNG only contains this excess carbon and not the energy from biomass, it is, therefore, not appropriate to say that the gas is produced from biomass (*see* also [80] [78]). Such a conclusion is supported by Directive (EU) 2015/652 on

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[74] Amendment of the 2009 Renewable Energy Directive by way of Directive (EU) 2015/1513

[75] Now included under Article 2(u) of the 2009 Renewable Energy Directive (2009/28/EC) and Article 2(s) of the Recast Renewable Energy Directive.

[76] Article 17(2) of the 2009 Renewable Energy Directive (2009/28/EC).

[77] As the sustainability criteria in the 2009 Renewable Energy Directive only apply to biofuels (only transport) and bioliquids (only liquids), they do not apply to solid and gaseous biomass sources in electricity, heating and cooling. To remedy this gap, the Recast Renewable Energy Directive extends the scope of application of these criteria to include biomass fuels which are gaseous and solid fuels produced from biomass for electricity and heat production. *See* also the respective definitions of all these substances in Article 2 of both the 2009 Renewable Energy Directive (2009/28/EC) and the Recast Renewable Energy Directive.

[78] Article 2(e) of the 2009 Renewable Energy Directive (2009/28/EC).

calculation methods and reporting requirements for fuel quality (to be discussed in *sub*section 8.5.3). This Directive includes under the category *"fuels other than biofuels and electricity"*:[79]

- electrolysis fully powered by non-biological renewable energy for the production of compressed hydrogen;
- Sabatier reaction of hydrogen from non-biological renewable energy electrolysis for the production of compressed synthetic methane.

The conclusion thus seems to be that the sustainability criteria for biomass related products do not apply to SNG, even when the carbon source is of a biogenic origin. The outcome may, however, be different when hydrogen is added to the raw biogas itself for biological methanation (*see* the second power-to-gas concept as presented under section 2.1).[4] Then, the majority of the methane, and thus the energy content, in the produced gas stems from the biomass itself. Under such circumstances it is most likely that the sustainability criteria do apply.

Although the sustainability criteria do not seem to apply when only the biogenic carbon released by biomass is used for the production of SNG, it is possible to have this biogenic carbon, or the SNG itself, certified under a voluntary scheme which has been approved by the European Commission. Such certification may serve as proof to the SNG consumer that the carbon source stems from sustainably grown biomass.[80]

8.4 Guarantees of Origin for Substitute Natural Gas

Besides being recognised by legislators as renewable energy, it is equally important that the final consumer can distinguish between gas from fossil sources, and gases of a renewable nature such as SNG. The tool prescribed by the Renewable Energy Directive for the disclosure of information to consumers regarding the source of energy is the guarantee of origin. As guarantees of origin allow consumers to verify the renewable origin of a gas, the existence thereof is considered a prerequisite for the (cross-border) trade in gases from renewable sources. Differentiation between "grey" and "green" energy also allows producers/suppliers of SNG to ask a premium price for their sustainable product.

Both the 2009 and the Recast Renewable Energy Directive define guarantees of origin as:

> *"guarantee of origin means an electronic document which has the sole function of providing proof to a final customer that a given share or quantity of energy was produced from renewable sources".*[81]

As the definition clearly states, guarantees of origin serve no other purpose under the Renewable Energy Directive than showing a final customer that the energy consumed was produced from renewable sources. Accordingly, a guarantee of origin enables to track a quantity of energy from a renewable source throughout the whole supply chain, from producer to consumer. A clear regulatory deficiency of the guarantee of origin scheme under the 2009 Directive is, however, that it only applies to electricity, heating and cooling produced from renewable sources.[82] There is no mention of an obligation for Member States to issue guarantees of origin for gases from a renewable source. This explains why the 2009 Renewable Energy Directive links the function of such electronic documents to the obligation for Member States to ensure that final customers are informed about the share of each energy source in the fuel mix for *electricity* production of their

[79] Part 2 of Annex I to Council Directive (EU) 2015/652 on fuel quality calculation methods and reporting requirements.
[80] https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes.
[81] Article 2(j) of the 2009 Renewable Energy Directive (2009/28/EC).
[82] Article 15(6) of the 2009 Renewable Energy Directive (2009/28/EC).

supplier.[83] In order to remedy this regulatory deficiency, the proposed Recast Renewable Energy Directive now includes renewable gas. In recital 47 it reads:

> *"Guarantees of origin, which are currently in place for renewable electricity and renewable heating and cooling, should be extended to cover renewable gas. This would provide a consistent means of proving to final customers the origin of renewable gases such as biomethane and would facilitate greater cross-border trade in such gases. It would also enable the creation of guarantees of origin for other renewable gases such as hydrogen."*

Guarantees of origin can be traded and transferred independently from the physical flow of energy.[84] In order to stimulate cross-border trade in renewable energy, Member States have an obligation to recognise guarantees of origin issued by other Member States.[85] Member States need to ensure, however, that the same unit of energy from renewable sources is taken into account only once, and that only one guarantee of origin is issued for each unit of energy produced.[86] This uncoupling of the physical flow of energy from the renewable origin of the energy allows, for example, for the sale of green electricity from Iceland to Belgium.[82] Even when there exists no physical cable between the two countries. As the guarantee of origin issued for a unit of electricity from renewable sources produced in Iceland is then sold to a Belgium supplier, the physical electricity consumed in Iceland can no longer be considered green. For this reason, Icelandic consumers may read on their electricity bill that part of their electricity stems from nuclear, while there are no nuclear plants in Iceland. As the independent trade in guarantees of origin awards generators or producers of energy from renewable sources a premium on top of the wholesale energy price, this trade stimulates further investments in renewable energy.[83]

Under the 2009 Renewable Energy Directive it is determined that guarantees of origin need to be cancelled by the issuing body 12 months after production or when the energy is consumed.[87] The lifespan of all guarantees is thereby in potential of an equal duration. In the proposal for a Recast Renewable Energy Directive, the validity of a guarantee of origin is limited to the calendar year in which the energy unit is produced plus six months.[88] It may, however, take a few months after production before a guarantee of origin is issued.[84] As remarked by the Association of Issuing Bodies (AIB) in their comments on the proposed scheme: "*[t]his validity period means that a Guarantee of Origin (GO) issued in January for energy produced in the same month has a shelf life of 17 months; while a GO issued in March for energy produced in December has a shelf life of 3 months.'*[84] According to the AIB, this may result in a fragmentation of the market in guarantees of origin. Importantly for power-to-gas through which renewable energy can be stored on a seasonal timeframe, the short shelf life of energy produced near the end of the calendar year may make it unattractive to subsequently store these gases for longer periods of time.

Another new feature in the proposed scheme is that Member States are required to ensure that no guarantees of origin are issued to a producer that receives financial support from a support scheme for the same production of energy from renewable sources.[89] Under the 2009 scheme Member States where still allowed the freedom to decide whether they would do so or not. It is proposed by the Commission in the Recast Renewable Energy Directive that guarantees of origin issued for a produced unit of energy for which a producer who also receives support will be transferred to the market by auctioning. As a result, the producer cannot sell its energy as

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[83] Article 15(1) of the 2009 Renewable Energy Directive (2009/28/EC) in conjunction with Article 3(9) of the 2009 Electricity Directive (2009/72/EC).
[84] Recital 52 of the 2009 Renewable Energy Directive (2009/28/EC).
[85] Article 15(9) of the 2009 Renewable Energy Directive(2009/28/EC).
[86] Article 15(2) of the 2009 Renewable Energy Directive(2009/28/EC).
[87] Article 15(3) of the 2009 Renewable Energy / Directive (200928/EC).
[88] Article 19(3) of the Recast Renewable Energy Directive (COM(2016) 767 final/2).
[89] Article 15(3) of the Recast Renewable Energy Directive (COM(2016) 767 final/2).

"renewable" unless he acquires new guarantees of origin on the market. The ratio behind this auctioning is that renewable energy producer should not be double compensated.[90] Potentially, this could have as a consequence that operators of a power-to-gas plant who receive financial support in the form of, for example, a tax or tariff exemption, cannot sell these gases in combination with a document guaranteeing that the energy originates from a renewable source. A better alternative would be to allow Member States to subtract the sale value of the guarantees of origin from the definite amount of financial support.

The inclusion of "renewable gases" under Recast Directive is a positive development. Nevertheless, in line with the comments made by the AIB, certain issues require further clarification:[84]

- how do guarantees of origin for different forms of energy (e.g. electricity and gas) interact when one form of energy is converted into another? For example, does conversion from one unit of energy to another "reset" the validity?
- Will the introduction of guarantees of origin for renewable gas be accompanied by a disclosure obligation for gas similar to that of electricity?

Other issues which need to be clarified are:

- What is exactly understood as "renewable gas"? As already discussed, the Recast Renewable Energy Directive does not contain a definition of this term. Are Member States free to set their own benchmarks with regard to, for example, the carbon source for the production of SNG?
- How does the proposed time of validity relate to the conversion and seasonal storage of energy?

8.5 Measures Promoting the consumption of Substitute Natural Gas

The scope of the STORE&GO project is not limited to the mere production of SNG through power-to-gas, but includes an assessment of future business models and end-uses (covered by Workpackage 8 of the STORE&GO project). As was already discussed under Chapter 2, SNG can be used to decarbonise the transportation and (industrial) heating/cooling sectors. This section will review certain measures under the 2009 and Recast Renewable Energy Directives which may stimulate the consumption of SNG in these sectors. First, subsection 8.5.1 will discuss how the consumption of SNG for different end-uses may be taken into account by the Member States in the calculation of the share of renewable energy in total national gross final consumption of energy, and thus towards the achievement of their mandatory targets. Subsequent subsection 8.5.2 will discuss measures which may promote the consumption of SNG for (industrial) heating purposes. Finally, subsection 8.5.3 will review how obligations for fuel suppliers may promote the use of SNG in the transportation sector.

8.5.1 Substitute Natural Gas in the Calculation of the Share of Energy from Renewable Sources

The total national gross final consumption of energy from renewable sources is calculated as the sum of the gross final consumption of: [91]

a) electricity from renewable energy sources (RES-E);
b) of energy from renewable sources for heating and cooling (including industry and households) (RES-H&C), and;
c) of energy from renewable sources in transport (RES-T).

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[90] Recital 54 of the Recast Renewable Energy Directive (COM(2016) 767 final/2).
[91] Article 5 of the 2009 Renewable Energy Directive (2009/28/EC). and Article 7 of the Recast Renewable Energy Directive (COM(2016) 767 final/2).

The share of energy from renewable sources in a sector is, as a basic rule, calculated by dividing the amount of energy from renewable sources (numerator) by the total energy consumption (denominator) in that sector. SNG thus only counts towards the share of energy from renewable sources in so far as it is allowed to be included in the numerator in a certain sector. If this is not the case, the consumption of SNG will not contribute towards the achievement of the national mandatory targets by the Member States.[85][86] As the conversion of energy from one energy carrier to another could, however, lead to double counting, gas, electricity and hydrogen produced from renewable sources are allowed to be counted only once towards either RES-E, RES-H&C, or RES-T.[92] In the following sub-section, the calculation of the share of energy from renewable sources in each sector will be briefly discussed.

8.5.1.1 Calculating RES-E

As the source of electricity cannot be identified at the point of end-use, the gross final *consumption* of electricity under (RES-E) is calculated as the quantity of electricity *produced* from renewable sources in a Member State.[93] With regard to electricity production by multi-fuel plants who use both renewable and fossil sources, only the electricity produced from renewable sources shall be taken into account. As the numerator for calculating RES-E only includes electricity directly generated from renewable sources (hydro, geothermal, solar, tidal, wave, ocean, wind, and biomass including biogas and bio liquids), electricity production from SNG is currently not yet accounted for.[86] It is therefore more likely that the initially generated electricity, before being converted into hydrogen, will be accounted for as RES-E.

8.5.1.2 Calculating RES-H&C

The gross final consumption of energy from renewable sources for heating and cooling consist of the quantity of district heating and cooling produced from renewable sources, plus the consumption of other energy from renewable sources in industry, households, services, agriculture, forestry and fisheries for heating, cooling and processing purposes.[94] Technologies which may contribute towards the binding 2020 targets are geothermal, solar, biomass (including solid, biogas, and bioliquids) and heat pumps.[86] Notably, also the share of biogas blended in the natural gas network is eligible to be counted towards the numerator.[86] However, similar to the situation for RES-E, SNG cannot yet be accounted for under RES-H&C. This is the same for the heat produced as a by-product of the exothermic methanation process.

8.5.1.3 Calculating RES-T

There exists a paradox on the contribution of synthetic fuels of renewable origin such as SNG towards the achievement of the 10 percent RES-T target. On the one hand, the energy content of the fuels listed under Annex IX to the 2009 Renewable Energy Directive count double towards the RES-T target (for the direct use of electricity from renewable sources in transportation this multiplier is five).[95] Included in the list of fuels under Annex IX are:

> *Entry (r): Renewable liquid and gaseous transport fuels of non-biological origin, and;*
>
> *Entry (s): Carbon capture and utilisation for transport purposes, if the energy source is renewable (…).*

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[92] Article 5(1) of the 2009 Renewable Energy Directive (2009/28/EC).
[93] Article 5(3) of the 2009 Renewable Energy Directive (2009/28/EC).
[94] Article 5(4) of the 2009 Renewable Energy Directive (2009/28/EC).
[95] Article 3(4)(c) and (f) and Annex IX to the 2009 Renewable Energy Directive (2009/28/EC). Annex IX has been introduced into the 2009 Renewable Energy Directive (2009/28/EC) by way of amendment through Directive (EU) 2015/1513.

Under the definition of entry (r) can also be understood synthetic fuels which are produced from electricity generated from wind or solar power.[86][78][96] Alternatively, SNG for transport purposes can be categorized under entry (s). It follows that SNG may thus contribute double towards the achievement of the RES-T share. A condition is, however, that the electricity used for its production is deducted from total electricity production in calculating RES-E.[86]

On the other hand, Regulation (EC) No 1099/2008 on energy statistics, which prescribes the methodology and definitions used in the calculation of the share of energy from renewable sources, does not take synthetic fuels into account because of its "current statistical insignificance".[86][87] Moreover, Annex III to the 2009 Renewable Energy Directive, which prescribes the energy content of different fuels, does not provide a calorific value for synthetic gases of non-biological origin. Among the fuels of which the energy content is awarded, are biomethanol (20 MJ/kg), biogas/biomethane 50 MJ/kg), and Fischer Tropsch diesel (44 MJ/kg).

In conclusion, the consumption of SNG cannot be fully accounted for by Member States when reporting on the share of renewable energy in gross final energy consumption. However, as can be read in the statistics sharing manual provided by EUROSTAT: *"this approach might change in the future if synthetic fuels of renewable origin are used to a significant scale as transport fuel."*[86]

8.5.1.4 Novelties under the Recast Renewable Energy Directive

The proposal for a Recast Renewable Energy Directive does not prescribe national mandatory targets beyond those for 2020. Instead, a Union wide target of at least a 27 percent share of renewable energy is introduced for 2030.[97] The novelties in the Recast Directive with regard to the calculation of the share of renewable energy sources are particularly relevant for the calculation of RES-T. The newly proposed Article 7(4)(a) reads:

> *"renewable liquid and gaseous transport fuels of non-biological origin that are produced from renewable electricity shall only be considered to be part of the calculation (of RES-E) pursuant to paragraph 1(a) when calculating the quantity of electricity produced in a Member State from renewable energy sources."*

If this provision will be included in the eventually adopted Recast Renewable Energy Directive, SNG will not count towards the share of RES-T, but to RES-E. As, however, the minimum RES-T target of 10 percent is removed in the proposal, this won't have an impact for compliance by the Member States with their overall renewable energy targets.

8.5.2 Substitute Natural Gas for Heating

Besides producing heat by burning SNG, heat is also produced during the power-to-gas process itself due to the exothermic nature of the methanation processes.[4] This heat can be utilised by other industries or be fed into the local district heating. For example, the heat produced at the STORE&GO plant in Falkenhagen (Germany) is transferred through a heat transfer line to a veneer mill in the vicinity of the plant, and the heat produced by the plant in Troia (Italy) is directed to the ambient carbon capture unit. The heating sector, including heat for industrial processes, and EU measures aimed at the decarbonisation of this sector, are thus of relevance to power-to-gas.

The 2009 Renewable Energy Directive contains little reference to heating. More attention to this sector has been awarded in the 2012 Energy Efficiency Directive (2012/27/EU). This Directive contains a non-binding EU-wide energy efficiency target of 20 percent in 2020 and indicative targets for the individual Member States.[98] Among the measures to promote efficiency in the

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[96] Article 3(4)(c) and second paragraph of 3(4)(f) of the 2009 Renewable Energy Directive (2009/28/EC).
[97] Article 3 of the Recast Renewable Energy Directive (COM(2016) 767 final/2).
[98] Article 1(1) of the 2012 Energy Efficiency Directive (2012/27/EU).

supply and use of energy is the requirement for Member States to assess the potential of "useful heat" from high efficiency cogeneration (which can use SNG) and the use of renewables and waste heat in efficient district heating and cooling.[99] Furthermore, system operators in charge of dispatch are required to award priority and guaranteed grid access and priority dispatch to electricity from high-efficiency cogeneration.[100] This preferential treatment may not, however, hamper the priority dispatch or access from variable renewable sources such as wind or solar.

In order to develop a more comprehensive EU strategy on the role of heating (and cooling) sector for the achievement of the Union's energy and climate goals, the European Commission issued in 2016 a Communication titled *"An EU Strategy for Heating and Cooling"*. According to the Communication, half of the energy in the EU is consumed through heating or cooling.[88] Of this energy, 75 percent is of a fossil origin, of which nearly half is natural gas. Much of this energy is wasted due to inefficient production processes and the absence of incentives to capture the released heat. Accordingly, the twofold challenge for the heating and cooling sector is to decarbonise and to become more efficient.

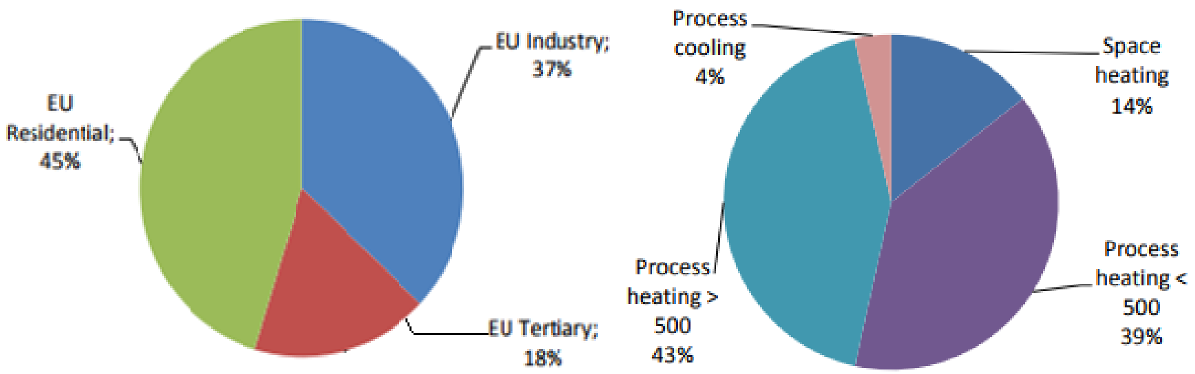

Figure 8-1 : *Left*: heating and cooling final energy consumption share in per sector (tertiary share represents the service sector) (2012); *Right:* heating and cooling final energy consumption in the industry sector (2012). (diagrams by [88])

An important pillar of the proposed strategy is the promotion of renewable-based heating and cooling. Accompanying the Communication by the Commission is a Staff Working Document which provides detailed information about different technologies which may contribute to this end.[89] Relevant for power-to-gas is the inclusion of:

- energy storage and the need thereof to become part of the market regulatory framework allowing it to participate in electricity and the heating and cooling supply on equal footing with other balancing and flexibility mechanisms. However, only hydrogen storage is mentioned under Annex V on energy storage technology;
- combined heat and power (CHP) used to generate electricity and useful heat in a single process based on primary energy inputs.

The EU heating and cooling strategy will for a large part be transformed into legislative measures through the Commission's proposals for a Recast Renewable Energy Directive. Article 23 of the Recast Renewable Energy Directive is titled *"mainstreaming renewable energy in the heating and cooling installations"*. This Article requires Member States to *"endeavour"* to increase the share of heating and cooling from renewable energy with at least 1 percent per year, expressed in terms of national share of final energy consumption. To this end, Member States *"may"* designate entities like fuel suppliers which shall contribute to this target, and *"may"* make public a list of measures. Among these measures is *"the physical incorporation of renewable energy in the energy, and energy fuel, supplied for heating and cooling".* This could stimulate Member States to support the

[99] Article 2(32) and Article 14 of the 2012 Energy Efficiency Directive (2012/27/EU).
[100] Article 15(5) of the 2012 Energy Efficiency Directive (2012/27/EU).

consumption of SNG for heating and/or cooling. However, the terms “endeavour” and “may” already indicate that Member States cannot be forced to implement this Article.

Subsequent Article 24 addresses district heating and cooling. Relevant for power-to-gas plants which are located near a residential area is the obligation for Member States to ensure non-discriminatory access to district heating or cooling systems for heat produced from renewable energy sources and for waste heat or cold.[101] “Waste heat” is defined as *“heat or cold which is generated as by-product in industrial or power generation installations and which would be dissipated unused in air or water without access to a district heating or cooling system”.*[102] The heat produced during the exothermic methanation process would fit this definition, and should, therefore, be allowed non-discriminatory access to district heating and cooling systems.

8.5.3 Substitute Natural Gas for Transportation

Besides the sector specific target of 10 percent renewable energy in RES-T which must be met by the Member States under the 2009 Renewable Energy Directive, the existing legal framework also prescribes an obligation for fuel suppliers to decarbonise their fuel mix. The Fuel Quality Directive (98/70/EC) sets targets for the reduction of life cycle greenhouse emissions of transport fuels.[90] Member States need to require suppliers to reduce, as gradually as possible, life cycle greenhouse gas emissions of the fuels in their fuel mix by at least 6 percent at end of 2020 compare to a 2010 baseline.[103] This baseline is based on the average fossil fuel consumption of petrol, diesel, gasoil, LPG and CNG in the EU in 2010 and is set at 94,1 gCO2eq/MJ.[104] Suppliers are thus encouraged to substitute the fossil fuels in their supply mix for fuels of a renewable origin with lower greenhouse gas emissions per unit of energy, for example by including SNG produced through power-to-gas in their supply mix.

The Fuel Quality Directive delegates the Commission to adopt greenhouse gas emission default values for renewable liquid and gaseous transport fuels of non-biological origin and carbon capture and utilisation for transport purposes.[105] Such default values must be based on a life-cycle approach. The Commission has made use of its delegated powers by issuing Directive (EU) 2015/652 on calculation methods and reporting requirements for fuel quality. Table 8-2 below provides an overview of gases relevant for power-to-gas technologies.

[101] Article 24(4) of the Recast Renewable Energy Directive (COM(2016) 767 final/2).
[102] Article 2(y) of the Recast Renewable Energy Directive (COM(2016) 767 final/2).
[103] Article 7(a) of the Fuel Quality Directive (98/70/EC).
[104] Annex II to Council Directive (EU) 2015/652 on calculation methods and reporting requirements for fuel quality.
[105] Article 7(a)(6) of the Fuel Quality Directive (98/70/EC).

Raw material source and process	Fuel placed on the market	Life cycle GHG intensity (gCO2eq/MJ)
Natural Gas, EU mix	Compressed Natural Gas in a spark ignition engine	69.3
Natural Gas, EU mix	Liquefied Natural Gas in a spark ignition engine	74.5
Electrolysis fully powered by non-biological renewable energy for the production of compressed hydrogen.	Compressed Hydrogen in a fuel cell	9.1
Natural gas using steam reforming	Compressed Hydrogen in a fuel cell	104.3
Sabatier reaction of hydrogen from non-biological renewable energy electrolysis	Compressed synthetic methane in a spark ignition engine	3.3

Table 8-2: Average life cycle greenhouse gas intensity default values for fuels other than biofuels and electricity

When added up, the default value for the entire two-step power-to-gas process is (9.1 + 3.3) 12.4 gCO2-eq/MJ.

The greenhouse gas emissions reduction target for suppliers under the Fuel Quality Directive will not be preceded by a new target for the post-2020 era. Instead, the decarbonisation of the transport sector will be addressed through a "blending obligation" for fuel suppliers under Article 25 of the Recast Renewable Energy Directive. [91][106] This blending obligation requires fuel suppliers to include a minimum share of at least 1.5 percent in 2021 and 6.8 percent by 2030 of the following fuels in their supply mix:

- advanced biofuels and other biofuels and biogas produced from feedstock listed in Annex IX;
- renewable liquid and gaseous transport fuels of non-biological origin;
- waste-based fossil fuels;
- renewable electricity.[107]

SNG fits under the category "renewable liquid and gaseous transport fuels of non-biological origin". The inclusion of this category covering SNG could be seen as a positive development for power-to-gas. However, the perceived contribution of non-biological renewable gases towards the 6,8 percent target can be considered to be somewhat modest. Article 25 determines that 3,6 percent of the 6,8 percent target by 2030 must be met by advanced biofuels listed under Annex IX(A) to the Recast Renewable Energy Directive. As this only applies to advanced *bio*fuels, SNG is not covered under any of the fuels or feedstocks listed under this Annex. Furthermore, used cooking oil, certain animal fats, and molasses from sugar refinery, listed under Annex IX(B), may contribute up to 1,7 percent. This would leave (only) 1,5 percent for renewable fuels of non-biological origin and renewable electricity. How the share of different fuels in a blending obligation may look like when

[106] Article 25 of the Recast Renewable Energy Directive. A "fuel supplier" is defined under Article 2(gg) as an *"entity supplying fuel to the market responsible for passing fuel or energy through an excise duty point or, where no excise is due, any other relevant entity designated by a Member State".*

[107] Article 25(1) of the Recast Renewable Energy Directive (COM(2016) 767 final/2).

the minimum of Annex IX(A) fuels are included, and the maximum of Annex IX(B) fuels, is presented below in Figure 8-1.

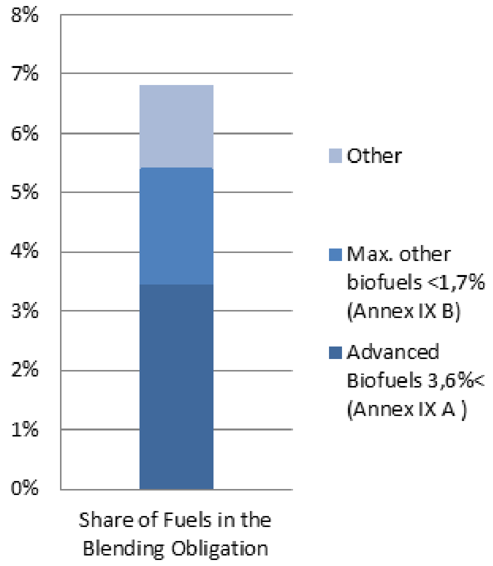

Figure 8-1: Share of Fuels in Blending Obligation (source: author)

An important question is how to calculate the share of renewable energy if a fuel is produced from electricity. Article 25 of the Recast Renewable Energy Directive provides two alternatives for determining the renewable energy content in such fuels, including SNG.[108] First, when the electricity which is fed into the electrolyser is withdrawn from the grid, the share of renewable energy in SNG may be calculated by either using the RES-E mix of the Union, or the national RES-E mix. This allows to “cherry pick” the highest RES-E percentage. Second, the energy may be counted as 100 percent renewable when the electricity is obtained through a direct connection to an installation generating renewable electricity that (i) comes into operation after or at the same time as the installation producing the renewable liquid and gaseous transport fuel of non-biological origin, and (ii) is not connected to the grid. What this means is, first, that the possibility to fully cover electricity from the grid with guarantees of origin in order to label the electricity which is fed into the electrolyser as 100 percent renewable is excluded from the proposal by the Commission. Second, even a direct line to an installation which generates renewable electricity does not lead to fully renewable input when this installation is simultaneously connected to the grid. It is then merely the national or Union-wide electricity mix which defines the renewable content of the produced hydrogen.

[108] Article 23(3) of the Recast Renewable Energy Directive (COM(2016) 767 final/2).

9 Financial (Dis-)incentives

Key Findings

- National support schemes for SNG have to conform with EU rules on state aid, including the 2014 guidelines on state aid for environmental protection and energy
- The guidelines do not prescribe specific conditions for schemes related to power-to-gas or SNG. Several conditions in the guideline may, however, (by analogy) serve as a benchmark for national support schemes for SNG and/or power-to-gas installations
- The 2014 guidelines on state aid for environmental protection and energy allow Member States to exclude energy intensive industries to be exempted from paying green surcharges. The guidelines prescribe for which activities exemptions are allowed and include SNG production
- Power-to-gas operators may have to pay network tariffs both as consumer when withdrawing electricity from the grid and as producer when discharging the energy on the electricity or gas network. The Recast Electricity Directive allows the Commission to adopt a guideline on network tarification for energy storage
- More specific clarification is required on the issue whether the capture and transfer of fossil CO_2 for CCU, for example as feedstock for SNG, needs to be covered by allowances under the EU emission trading scheme
- Consideration is needed on whether SNG produced from a biogenic or ambient carbon source should be equally exempted from the EU emission trading scheme as biomass and biogas

9.1 Introduction

This Chapter will address various financial incentives and disincentives which have an effect on the investment and operation costs of a power-to-gas facility. Section 9.2 will review the legal framework for support schemes. This will include an examination of the conditions for support for biomethane and electricity production which may also be relevant for SNG. Section 9.3 and 9.4 will address green surcharges and network tariffs. Both add up to the wholesale price of electricity, thereby contributing to the costs of producing hydrogen. Final section 9.5 will discuss carbon pricing measures which may incentivise the recycling of fossil carbon and the consumption of SNG.

9.2 Support Schemes

This section will assess to what extent European legislation allows for possible national support schemes for SNG produced by power-to-gas facilities. Support schemes enable gases from renewable sources to be competitive with their fossil equivalent: natural gas.[92] Depending on the cost reduction curve of technology involved in the power-to-gas process, SNG production may also require financial support in order to become an attractive alternative to fossil energy.

Article 3(3)(a) of the 2009 Renewable Energy Directive allows Member States to provide financial support for the promotion of the use of energy from renewable sources. According to the definition of the term “support schemes” in this Directive, such a scheme may be aimed at reducing the costs of such energy, increasing the price at which it can be sold, or stimulating consumption by obligating certain entities to consume a minimum volume of energy from renewable sources.[109] The definition also provides a non-exhaustive list of tools which Member States may introduce to achieve these aims: investment aid, tax exemptions or reductions, tax refunds, renewable energy obligations, and direct price support schemes such as feed-in tariffs and premium payments.

As support measures for a particular technology or activity have a potentially market distorting effect, Member States are not awarded full discretion in how they design their national support schemes.[93] Such measures must be compatible with the European rules on state aid.[110] In order to provide guidance to Member States on the conditions related to such compatibility, the European Commission has issued a non-binding guidance document on "State aid for environmental protection and energy 2014-2020" (hereafter "2014 State Aid Guidelines").[93][111] Although of a non-binding character, these guidelines support the European Commission in making decisions on the compatibility of a support scheme with European law.

Even though the 2014 State Aid Guidelines contain no specific conditions for support schemes for power-to-gas facilities or SNG, they do contain a few conditions which may nevertheless (by analogy) serve as a benchmark against which national support schemes can be evaluated in Deliverable 7.3 on national law applicable to power-to-gas:

- Aid *per unit of energy* (also known as operating aid) may not exceed the difference between the total levelised costs of producing energy (LCOE) and the market price of the form of energy concerned. The LCOE may include a normal return of capital. Received aid for CAPEX (known as investment aid) must, however, be deducted when calculating the LCOE. Aid may only be granted until the plant has been fully depreciated;[112]
- For biomass plants, including the production of biogas, of which the investment costs are relatively low but operation costs relatively high, operation aid is still allowed after the plant has been fully depreciated if a Member State demonstrates that the operating costs borne by the beneficiary after plant depreciation are still higher than the market price of the energy concerned. The measure may compensate the difference in operating costs borne by the beneficiary and the market price;[113]
- If a (bio)fuel is already subjected to a supply or blending obligation, further aid is not considered to increase the level of environmental protection and is therefore not allowed. This is different where a Member State can demonstrate that the aid is limited to sustainable (bio)fuels that are too expensive to come on the market with a supply or blending obligation only;[114]
- Fixed feed-in tariffs for electricity from renewable sources are no longer allowed since 1 January 2016 as such a guaranteed returns are considered to distort prices in the electricity market and may result in windfall profits for generators[94] [115] Instead, fixed feed-in tariffs need to be phased out and be replaced by market price premium schemes whereby generators sell their electricity directly in the market.[116]

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[109] Article 2(k) of the 2009 Renewable Energy Directive (2009/28/EC).

[110] Article 107(1) of the Treaty on the Functioning of the European Union reads: "any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favoring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the internal market.".

[111] The 2014 State aid Guidelines are based on Article 107(3)(C) of the Treaty on the Functioning of the European Union which allow the European Commission to consider compatible with the internal market State aid to facilitate the development of certain economic activities.

[112] Section 3.3.2.2., paragraph 131 of the 2014 State aid Guidelines.

[113] Section 3.3.2.3., paragraph 132-133 of the 2014 State aid Guidelines.

[114] Section 3.3.1., paragraph 114 of the 2014 State aid Guidelines.

[115] Section 3.3.2.1., paragraph 124 of the 2014 State aid Guidelines. Exemptions exist for small production units (less than 500 KW) and small windfarms (below 3 MW or 3 generation units).

[116] Section 3.3.2.1., paragraph 124-126 of the 2014 State aid Guidelines.

9.3 Exemptions for Green Surcharges for the Financing of Support Schemes

Green surcharges are tax or non-tax levies which are paid by electricity consumers in order to finance support schemes for renewable energy projects.[95] Such surcharges are stacked on top of the wholesale price of energy and other energy consumption taxes. As electricity is the main feedstock for the production of hydrogen during the first step within the power-to-gas process, this accumulation of cost elements has a potential negative effect on the business case of power-to-Gas. This sub-section explores to what extent the already discussed 2014 State Aid Guidelines allow certain electricity consumers to be exempted from green charges.

As tax exemptions have a potential market distorting effect these are covered under the previously discussed 2014 State Aid Guidelines.[117] The principle rule is that, when the costs of financing renewable energy support are recovered from energy consumers, they should be recovered in a way that does not discriminate between consumers of energy. The guidelines do, however, allow Member States to exempt an undertaking from having to pay green surcharges or to grant an undertaking a reduction. The ratio behind this exemption is that energy intensive industries which have to compete on an international market may leave the Member State or the EU when the price of electricity as a feedstock is considered too high.[96] There are two grounds based on which an undertaking can be declared eligible for an exemption or reduction. The first ground is the inclusion of the sector in which the undertaking is active under Annex III to the 2014 State aid Guidelines. Of relevance to power-to-gas is the inclusion under this Annex of the manufacturing of organic and inorganic chemicals. As will be explained in section 10.3 on EU chemical legislation, these categories cover the production of hydrogen and SNG. The second eligibility ground concerns those undertakings active in a sector not covered under Annex III, but which have an electro-intensity of at least 20 percent and belong to a sector with a trade intensity of at least 4 percent.[118] When a sector is considered eligible, the aid in the form of exempted or reduced green surcharges must be granted in a non-discriminatory way to all competitors in that sector.

9.4 Network Tariffs

Producers, Storage operators, and consumers which are connected to a transmission or distribution network may be required to pay a tariff for the access or connection to this network. Such network tariffs are also commonly referred to as “usage charges”, “grid fees”, or “use of system charges”. As electricity is a feedstock for the production of hydrogen through water electrolysis, network tariffs which are stacked on top of the wholesale price of electricity will have a direct effect on the overall production costs. Tariffs can be divided into so called “G-charges” for producers connected to the network, and “L-charges” for loads, or end-users. Storage operators may, however, be required to pay both L-charges when withdrawing electricity from the grid, as well as G-Charges at the time of reinjecting energy into the electricity or gas grid. [26][97] The L-charges will again need to be paid by the final consumer of the previously stored electricity or gas. A review of recently published academic articles and opinion papers by industry stakeholders reveals that the abolishment of such double charges is considered to be one of the most crucial contributors to a profitable business case for energy storage facilities.[26][38][40][97][99] Similar outcomes have been found for power-to-gas.[100]

The 2009 Electricity and Gas Directives and Regulations do not prescribe detailed rules on how system operators may impose tariffs on system users for the construction, maintenance, and operation of the grid. The Directives and Regulations only provide limited guidance by requiring

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[117] *See,* section 3.7.2. of the 2014 State aid Guidelines.

[118] Trade intensity is an indicator to determine whether a sector exports more, as a percentage, to a trade partner than the other countries in the world do on average.

that tariffs must be objective, non-discriminatory, and cost-reflective.[119] In addition, a national regulator for the energy sector is required to give prior approval to the transmission and distribution tariffs or the methodologies underlying their calculation.[120] In absence of more detailed guidance, Member States have much discretion in how they regulate their national tariff systematics.

A recent overview provided by ENTSO-E on electricity transmission tariffs in 30 countries within European revealed that the system of grid or network usage charges across these countries is indeed of a heterogeneous nature.[101] Although all countries under assessment have established a regime for L-charges, only a minority of the countries extend the imposition of tariffs to generators through G-charges. There are a few countries which have introduced a regime of special tariff conditions for storage facilities, although often only pumped hydro storage is mentioned as eligible technology. Special tariff conditions for storage facilities range from discounted rates (e.g. Austria and Spain), to exemptions from L-charges (Serbia and Switzerland), to complete exemptions (e.g. Germany and Italy). The German legislation explicitly includes power-to-gas installation under this exemption, even when the energy stored is not reconverted into electricity.[102][121]

In anticipation of a revision of the Third Energy Package, multiple stakeholders have attempted to raise the issue of double charging and heterogeneity in the treatment of energy storage with the European Commission.[26][97] Various arguments have been brought forward in support of the abolishment of double network tariffs for storage facilities at the EU level. The first argument is that energy storage is not an act of end-use of electricity as the energy is stored with the intention of discharging the energy back into the system at a later point in time. Actual consumption of the energy will then take place by residential and commercial end-user applications. Therefore, the imposition of L-charges by storage operators is argued to be unfounded. [26][39][97] The second argument targets the levying of G-Charges. Heterogeneously imposed G-charges would have a potential distortionary effect on competition by creating locational advantages, resulting in sub-optimal investment decisions on generation and energy storage facilities.[103][104]

A possible improvement for storage operators, besides the partial and full tariff exemptions mentioned above, would be to introduce dynamic hourly network tariffs which reflect the variable rate by which the network is utilized during the day.[39][98] According to this "principle of cost causality", energy storage facilities which systematically charge during off-peak hours should not be burdened by costs which are earmarked for grid investments. Such an introduction of dynamic network tariffs would acknowledge the benefits energy storage can provide to the operation of the network. A 2013 exploratory paper by the Directorate Energy of the European Commission on energy storage was supportive of this idea.[31]

Another option for a special tariff regime for energy storage is to introduce a discount similar to the one awarded to energy flows from and to gas storage facilities. In order to come to a more homogeneous and transparent system of network tariffs in the gas sector, the European Commission has adopted at the beginning of 2017 a network code on harmonised transmission tariff structures for gas.[105] The objective of this network code is to contribute to market integration, enhancement of security of supply, and the promotion of interconnection between gas networks. An interesting feature in this network code is the introduction of a discount on tariffs at entry points from and exit point to gas storage facilities.[122] As illustrated below in Figure 9-1, the default rule is that a 50 percent discount is awarded on capacity-based transmission tariffs at entry-

[119] Article 32 of the 2009 Electricity Directive (2009/72/EC) and 2009 Gas Directive (2009/73/EC), Article 14 of the 2009 Electricity Regulation (EC) No 714/2009, and Article 13 2009 Gas Regulation (EC) No 715/2009.
[120] Article 37(6) 2009 Electricity Directive (2009/72/EC) and Article 41(6) 2009 Gas Directive (2009/73/EC).
[121] § 118 Abs. 6 Energiewirtschaftgesetz.
[122] Article 9 network code on harmonised transmission tariff structures for gas (EU) 2017/460.

and exit point of gas storage facilities connected to the network of one transmission system. As an exemption to this rule, in order to avoid a distortion of competition, the discount shall not be applied where a facility is connected to more networks than one transmission network and operates in competition with an interconnection point. The introduction of the 50 percent discount is intended to avoid double charging for transportation of gas to and from storage facilities. The underlying reason for having such a special regime is to acknowledge that gas storage facilities in general are considered to contribute to system flexibility and security of supply.[123] A similar line of reasoning in favour of an exemption or discount from tariff payments could made in the context of energy storage.

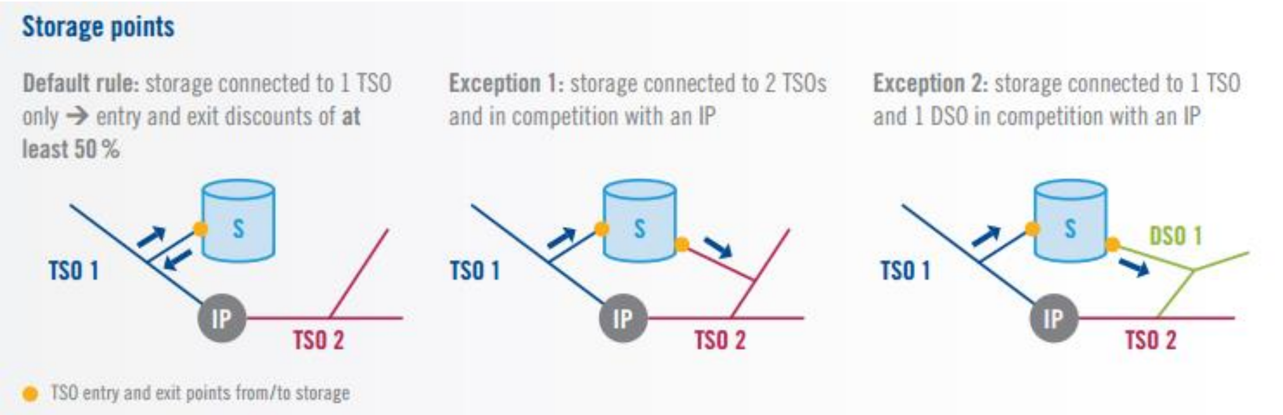

Figure 9-1: Tariff Discount at Entry- and Exit Points at Gas Storage Facilities under the Network Code on Harmonised Transmission Tariff Structures for Gas. "IP" stands for "interconnection point". (Image by [106])

The proposed Recast Electricity Regulation includes the statement that *"(network tariffs) should not discriminate against energy storage, and should not create disincentives for participation in demand response."*[124] Although this provision is a clear call on Member States to revaluate the applicability of network tariffs to energy storage, it does not unequivocally determine that double charging should be abolished. It can even be questioned what this passage adds to the general non-discrimination requirement under the 2009 gas and electricity Directives and Regulations. Of more interest is Article 57 of the Recast Electricity Regulation which would allow the Commission to adopt guidelines which: *"determine appropriate rules relating to charges applied to producers, energy storage and customers (load) under national distribution and transmission tariff systems and connection regimes."* However, an impact assessment accompanying the Clean Energy for All Europeans Package reveals that the Commission is not yet prepared to fully harmonise national tarification systems.[108] For the short term, the Commission will request ACER to develop, within the coming two years, principles on the setting of transmission tariffs.[108] Finally, with regard to dynamic network tariffs, the Recast Electricity Directive allows for differentiated tariffs at the distribution level, based on system users' consumption or generation profiles.[125]

9.5 Carbon Pricing

Carbon pricing aims for the internalisation of negative externalities in the costs of carbon emitting activities such as power generation through the incineration of coal. This section will look at three carbon price related incentives for the deployment of power-to-gas. The first two are related to the EU ETS, the third concerns the legal feasibility of the adoption of a carbon tax at the EU level .

[123] Recital 4 network code on harmonised transmission tariff structures for gas (EU) 2017/460.
[124] Recital 22 and Article 16(1) Recast Electricity Regulation (COM(2016) 861 final/2).
[125] Article 16(7) of the Recast Electricity Regulation (COM(2016) 861 final/2).

9.5.1 Carbon Capture and Utilisation under the EU Emission Trading Scheme

A cornerstone of EU efforts to limit greenhouse gas emissions and to incentivise the switch to low-carbon technologies is the EU Emission Trading Scheme (EU ETS). The rules under which the trading scheme operates are provided for in the EU ETS Directive (2003/87/EC).[109] The basic feature of the EU ETS is the cap-and-trade system. Under this system, a cap is imposed on the annually maximum amount of emissions which are allowed to be emitted by the covered installation.[110] Operators of installations can acquire the right, or allowance, to emit one tone of carbon dioxide through participating in an auction, or through subsequent trading.

The discussion on whether carbon capture and utilisation (CCU) should be covered under the EU ETS revolves around the question whether or not operators are, or should be, obliged to surrender allowances for CO_2 which they do not emit, but capture and transfer to other entities. If the answer to this question is negative, this creates a financial stimulus for operators to capture fossil CO_2 at end point, and to transfer the CO_2 out of the facility to, for example, an operator of a power-to-gas installation, which may use this as a feedstock for SNG production. It needs to be noted, however, that this scenario requires the price of an EU ETS allowance to exceed the costs for capturing carbon, which is currently not yet the case. This may change, however, when the technology for capturing CO_2 becomes cheaper due to the technology learning curve, and the price of an EU ETS allowance becomes higher due to the 2030 and 2050 EU climate targets.

Proponents of the exemption for operators to surrender allowances when CO_2 is captured for CCU may refer to the fact that the CO_2 is then not emitted into the atmosphere, but recycled into another product for a second use, which results in reduced emissions.[112][126] Critics of such an exemption argue, however, that this results in the absence of a carbon price which incentivises operators to shift to low-carbon fuels or production processes and, in addition, results in the "leakage" of fossil carbon from the ETS sector to the non-ETS sector, for example when the CO_2 is used for car fuel production.[111]

Turning to the situation under the current EU ETS Directive, the Directive contains an exemption for operators from the obligation to surrender allowances when the carbon is not emitted but captured and *permanently stored* in a facility with a permit in accordance with the Directive on the geological storage of carbon dioxide (2209/31/EC, hereafter "CCS Directive").[127] Further rules on CO_2 monitoring and reporting under the EU ETS are provided for in the Commission Regulation (EU) No 601/2012 on the monitoring and reporting of greenhouse emissions (MRG Regulation).[113] The rules include instructions on how to account for CO_2 emissions which are not emitted by an installation, but transferred out of the installation. Article 49 of this Regulation repeats what is stated in the EU ETS Directive on the exemption for the obligation to surrender allowances in the case of CCS. However, this Article in the Regulation adds: *"[f]or any other transfer of CO_2 out of the installation, no subtraction of CO_2 from the installation's emissions shall be allowed."*. The reason for such limitation is the closing of potential loopholes connected to the transfer of CO_2 which existed in the past when *any* transfer of CO_2 was still allowed to be subtracted from the emissions balance of an installation.[128] Such unlimited transfer possibilities allowed for the "leakage" of CO_2 emissions out of the EU ETS to non-ETS sectors.[114] By limiting the possibility of CO_2 transfer to CCS related transfers, an important incentive for operators to capture the carbon for utilisation pathways such as the production of SNG was removed.

[126] Although such carbon recycling may potentially lead to a 50 percent reduction in CO_2 emissions, a full life cycle assessment is required to calculate net emissions gains. *See* [78][79].
[127] Article 12(3a) of the EU ETS Directive (2003/87/EC).
[128] Recital 13 of Commission Regulation (EU) No 601/2012 on the monitoring and reporting of greenhouse emissions (MRG Regulation).

The validity of Article 49 of the MRG Regulation has recently been challenged before the European Court of Justice in a case on CCU under the EU ETS.[129] The court found that this Article was invalid under the given circumstances as the EU ETS Directive does not contain a similar provision as Article 49 of the MRG Regulation stating that no other CO_2 transfer would qualify for an exemption except for CCS. The fact that Article 49 of the MRG Regulation irrefutably rejects all other forms of CO_2 transfer was deemed to be invalid by the Court. The given circumstances were, however, that the CO_2 was transferred to an installation for the production of Precipitated Calcium Carbonate in which the carbon is chemically bound in a stable product.[130] As the consumption thereof does not lead to direct emissions, it is unsure what the effect of this case will be for the transfer of CO_2 for the production of fuels and other consumable gases of which the consumption does lead to direct CO_2 emissions.

It is not unlikely that in the future CO_2 subtraction of total emission will again be allowed for operators who transfer CO_2 out of the installation for CCU purposes. In its 2015 communication on the Energy Union Package, the European Commission included among its research priorities*: "[a] forward-looking approach to CCS and CCU for the power and industrial sectors, which will be critical to reaching the 2050 climate objectives in a cost-effective way. This will require an enabling policy framework, including a reform of the Emissions Trading System and the new Innovation Fund".*[115] During the ongoing negotiations for an EU ETS Directive for the post-2020 era, the European Parliament and Council have proposed to include CCU and energy storage in the list of technologies and processes which are eligible to receive a share of the 400 million free allowances reserved in the Innovation Fund for low carbon innovations.[116][131] As it stands today, the proposal for a revised EU ETS Directive also includes the remark that the long-term incentive for renewable energy and low-carbon technologies is *"the carbon price signal it creates and that allowances will not need to be surrendered for CO_2 emissions which are permanently stored or avoided".* It needs to be seen, however, how the production and consumption of SNG relates to the phrase "*permanently stored or avoided"*. In order to take away the uncertainty on the position of different CCU processes and products under the EU ETS, the Council and Parliament should address this issue during the negotiations on the EU ETS Directive for the post-2020 era.

9.5.2 Consumption of Substitute Natural Gas under the EU Emission Trading Scheme

The second issue in the context of the EU ETS relates to the question whether the emissions related to the *consumption* of gases which contain recycled carbon as a feedstock need to be covered by allowances. Giving rise to this question is the zero emission factor for biomass and the question whether such a zero emission factor should also be introduced for SNG.[132] What this zero emission factor means is that emissions from biomass do not need to be covered by ETS allowances. This exemption is a financial incentive in support of the consumption of biomass and related gases such as biogas and bioliquids. Operators may even take into account the share of biogas in the natural gas grid.[133] It could be argued that when SNG produced from a biogenic or ambient carbon source has a similar greenhouse gas balance as biogas, the consumption thereof should be awarded a similar zero rating.

[129] *See* European Court of Justice, Case C-460/15, 19 January 2017, *Schaefer Kalk GmbH & Co. kg v. Bundesrepublik Deutschland*.

[130] Precipitated Calcium Carbonate is a non-toxic mineral which can be used in a variety of products such as toothpaste or pharmaceuticals.

[131] Latest developments regarding the negotiations for a revised EU ETS Directive can be found on the EUR-Lex website: http://eur-lex.europa.eu.

[132] Annex IV to the EU ETS Directive (2003/87/EC).

[133] Article 38 of the MRG Regulation (EU) No 601/2012.

9.5.3 European Carbon Tax

Although the EU ETS is regarded as the centrepiece of the EU efforts to combat greenhouse gas emissions and the switch towards low-carbon technologies such as power-to-gas, it has not succeeded in driving up the price of carbon emissions.[134] An alternative tool for driving up carbon prices is the introduction of an EU-wide carbon tax. A carbon tax is a levy imposed on carbon emissions that are released due to the consumption of fossil energy sources. When well designed, such a tax would make gases from renewable sources more competitive in comparison to natural gas. This would require an exemption from the carbon tax when gases from renewable sources are consumed with a zero or negative greenhouse gas balance.

The largest legal barrier for the adoption of fiscal measures such as an EU-wide carbon tax is, however, the requirement that the Member States have to act unanimously.[135] This high voting threshold, in combination with the reluctance of Member States to cede authority in the field of taxation to the EU, explains why a proposal by the European Commission in 1992 for a tax on carbon dioxide emissions failed to get adopted.[117][118] Similarly, a proposal in 2011 to include a carbon tax under the scope of the Energy Taxation Directive (2003/96/EC) did not pass the voting threshold. In absence of the perspective of a EU-wide carbon tax, various Member States have adopted a national carbon tax scheme.[118]

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[134] At 25 October 2017, the price of a EU ETS allowance was €7.41. Between 2005–2009, this price fluctuated between €20 and €30. *See* www.eex.com and https://www.eea.europa.eu/data-and-maps/figures/eua-future-prices-200520132011.

[135] Article 113 of the Treaty on the Functioning of the European Union (OJ 2012 C 326/47).

10 European Environmental and Safety Law Related to the Deployment of Power-to-Gas facilities

Key Findings

- Depending on the interpretation of the term "integrated chemical installation" under the Environmental Impact Assessment Directive, the obligation for a developer of a power-to-gas installation to perform an environmental impact assessment flows automatically from its status as Annex I project, or may be left to the discretion of the Member States as is the case for Annex II project
- A power-to-gas facility producing hydrogen and/or SNG, which is not a research or test facility, has to operate under a permit under the Industrial Emissions Directive
- Producers of SNG have to comply with the registration requirements under the REACH Regulation. Although substances with similar characteristics are exempted from such the registration obligation, this is not the case for SNG due to its synthetic character
- Power-to-Gas developers and operators have to comply with the safety requirements under the SEVESOIII Directive
- It needs to be specified whether power-to-gas and energy storage projects are covered under the streamlined "one shop stop" permitting procedure as introduced under the Recast Renewable Energy Directive

10.1 Introduction

Environmental and safety law aims to prevent or limit adverse effects of an activity for human health and the environment. An important mechanism for authorities to ensure that project developers award sufficient consideration to potential risks is the authorisation procedure. The obligation for Member States to subject a certain activity to an authorisation procedure often stems from European environmental and safety law. Therefore, this Chapter will present a review and analysis of European environmental (section 10.2) and safety (section 10.3) legislation which is relevant for the deployment of projects such as the construction and operation of a power-to-gas plant. In addition, section 10.4 will explain to what extent EU legislation requires Member States to streamline their authorisation procedures in order to relieve the administrative burden of project developers.

10.2 European Environmental Law

This section on European environmental law will discuss certain instruments and the requirements contained therein which will need to be taken into account by the authorities of the Member States and developers of power-to-gas installation during the authorisation stage. Discussed will be the need for an environmental impact assessment (10.2.1), permit requirements flowing from the Industrial Emissions Directive (10.2.2), influence of the Habitats Directive on the location of power-to-gas installations (10.2.3), the relevance of the Water Framework Directive (10.2.4), and the Environmental Liability Directive (10.2.5.).

10.2.1 Environmental Impact Assessment Directive

The Environmental Impact Assessment Directive (Directive 2011/92/EU) (hereafter "EIA Directive") prescribes which activities need to be subjected to an environmental impact assessment.[119] An environmental impact assessment is an assessment of the potential environmental effects of certain projects and activities. The objective of the EIA Directive is to *"ensure that, before development consent is given, projects likely to have significant effects on the environment by virtue, inter alia, of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects on the environment."*[136]

10.2.1.1 Projects and Activities Falling Under the Scope of the EIA Directive

The obligation to execute an environmental impact assessment exists for those projects which will likely have a significant effect on the environment. The EIA Directive makes a distinction between projects which are assumed to have a definite significant effect, and those which likely, but not necessarily, have a significant effect. Projects falling under the first category are listed under Annex I to the EIA Directive and always need to be subjected to an assessment.[137] For certain activities under Annex I a quantitative threshold is provided. For projects falling under the second category, under Annex II, Member States have the discretion to determine whether a project shall be made subject to an assessment.[138] Member States can determine this on a case-by-case basis or based on pre-determined thresholds or criteria. These criteria include the size and design of the installation, use of natural resources, waste production, pollution and nuisance, risk of major accidents, risk to human health, ecological effects, density of the population in the area.[139] Furthermore, the magnitude, nature, likelihood, and intensity of the impact need to be taken into account. Annex I projects undertaken exclusively, or mainly, for the development and testing of new methods or products, and not used for more than two years, may be treated by the Member States as Annex II projects.[140] This allows Member States the discretion to relieve small and temporary research projects from the duty to perform an assessment.

The term "project" needs to be interpreted widely. The splitting up of projects which consist out of multiple linked processes or sub-projects in order to circumvent an obligation to perform an environmental impact assessment is not allowed.[120] Likewise, the cumulative effects of related projects need to be taken into account.[141] To come to a definite conclusion as to whether a project needs to be subjected to an assessment thus requires to consider the whole scope of the project, as well as the specific configuration of activities taking place within the project. This is also reflected in a passage on biogas related projects in a guidance note to the EIA Directive by the European Commission:

> *"From a production perspective, biogas can either be the main output of an activity, or its by-product. In addition, from a construction and maintenance perspective, biogas production relies on infrastructure, for instance pipelines, storage facilities, etc. Therefore, to determine whether a biogas related project falls under the scope of the EIA Directive, it has to be thoroughly examined with due account taken of all relevant perspectives."* [120]

Table 10-1 below provides an overview of activities listed under Annex I and Annex II which can be of relevance to the question whether power-to-gas projects need to be subjected to an assessment.

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[136] Article 1(2) of the Environmental Impact Assessment Directive (2011/92/EU).
[137] Article 4(1) of the Environmental Impact Assessment Directive (2011/92/EU).
[138] Article 4(2) of the Environmental Impact Assessment Directive (2011/92/EU).
[139] Annex III to the Environmental Impact Assessment Directive (2011/92/EU).
[140] Annex II entry 13(b) of the Environmental Impact Assessment Directive (2011/92/EU).
[141] European Court of Justice, Case C-392/96, *Commission v. Ireland,* [1999] ECR I-5901.

Activity in PtG chain	Annex I	Annex II
Electricity grid connection	Entry 20) Construction of overhead electrical power lines with a voltage of 220 kV or more and a length of more than 15 km	Entry 3(b) (…) transmission of electrical energy by overhead cables (projects not included in Annex I);
Hydrogen production through electrolysis		Entry 6(a) Treatment of intermediate products and production of chemicals
Production of substitute natural gas through electrolysis and methanation	Entry 6) Integrated chemical installations… …(a) for the production of basic organic chemicals[142] …(b) for the production of basic inorganic chemicals[143]	Entry 6(a) Treatment of intermediate products and production of chemicals
Hydrogen and SNG transportation	Entry 16(a). Pipelines with a diameter of more than 800 mm and a length of more than 40 km… …(a) for the transport of gas, oil, chemicals;	Entry 3(b) Industrial installations for carrying gas, steam and hot water; transmission of electrical energy by overhead cables (projects not included in Annex I);
Hydrogen storage		Entry 3(d) Underground storage of combustible gases; Entry 6(c) Storage facilities for (…) and chemical products.
SNG storage		Entry 3(c) Surface storage of natural gas Entry 3(d) Underground storage of combustible gases;
Re-electrification	Entry 2(a) Thermal power stations and other combustion installations with a heat output of 300 megawatts or more	Entry 3(a) Industrial installations for the production of electricity, steam and hot water (projects not included in Annex I);

Table 10-1: Activities listed in Annex I and II relevant for power-to-gas projects

When focussing solely on the Power-to-gas installation for the production of hydrogen and SNG, the main question is whether such an installation is considered as an “integrated chemical installation” under Annex I, Article 6(a) and (b), or an installation under Annex II, Article 6(a), “for the production of chemicals”.[144] The outcome to this question will determine whether Member

[142] The guidance document to the EIA Directive by the European Commission’s refers for the interpretation of the term “organic chemicals” to the Industrial Emissions Directive (*see* section 10.1.2). This Directive includes as organic chemical: *4.1(a) simple hydrocarbons (linear or cyclic, saturated or unsaturated, aliphatic or aromatic)*.

[143] Hydrogen on the other hand is classified as an inorganic chemical: 4.2(a) *“gases, such as (…) hydrogen”.*

[144] *See* footnote 147 and 148 above with regard to the classification of hydrogen and SNG as chemicals.

States are obligated to require power-to-gas plants, as Annex I activity, to perform an assessment, or have the discretion to exempt such plants, as Annex II activity, when the initial screening does not point to the likelihood of significant effects to the environment.

Certain guidance and clarification on what constitutes an “integrated chemical installation” is provided in Article 6 of Annex I itself: *“those installations for the manufacture on an industrial scale of substances using chemical conversion processes, in which several units are juxtaposed and are functionally linked to one another*”.[145] According to the European Court of Justice, whether a chemical installation is “integrated” depends on the *“existence of interlinked production units constituting in terms of their operation a single production unit.”*[121] The capacity of the installation, or type of substance produced, is thereby irrelevant. According to the court, quantitative criteria are only relevant where these are explicitly provided for in Annex I.

Accordingly, while a stand-alone electrolyser unit most likely does not fall under the definition of an “integrated chemical installation”, an installation which consists of an interlinked electrolyser and methanation unit most likely does. As a consequence, the obligation to perform an environmental impact assessment for only deploying an electrolyser seems to be left to the discretion of the Member States by way of Article 6 of Annex II. While for developers of a two-stage Power-to-SNG installation, this obligation seems definite by way of Article 6 of Annex I of the EIA Directive. Legal certainty would, however, be increased when the EIA Directive explicitly categorizes power-to-gas projects as falling under either Annex I or Annex II.

10.2.1.2 Procedure of the Environmental Impact Assessment

Where the conclusion is that an environmental impact is required, the first step in the procedure is the preparation of an impact assessment by the developer of a project. Article 5(1) and Annex IV provide details on the information which needs to be included in the assessment. This includes a description of the characteristics of the operational phase (e.g. energy demand and use of natural resources), possible adverse environmental effects, and preventive measures. As public consultation is an important element in the EIA Directive, Members States are required to allow the public and local authorities to express their opinion on the request for development consent.[146] The outcome of the consultation needs to be duly taken into account in the overall authorisation procedure.[147]

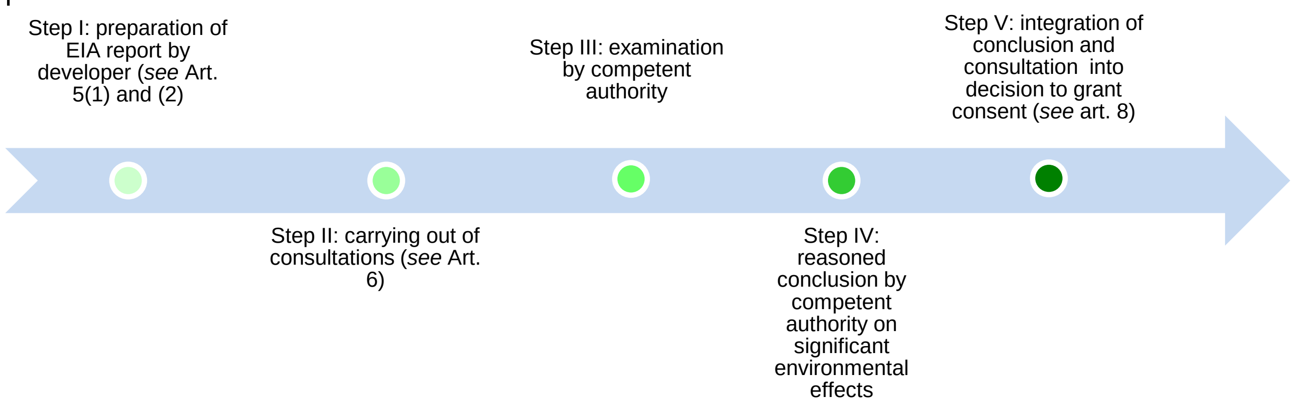

Figure 10-1: Overview of the Procedure under the EIA Directive

[145] According to the European Commission, the term ‘industrial scale’ does not refer to a quantitative capacity. Instead, if the activity is carried out for ‘commercial purposes’, it should be considered as production on an industrial scale, even if the material is an intermediate product and therefore not itself traded.[138]

[146] Article 6(1) and (2) of the Environmental Impact Assessment Directive (2011/92/EU).

[147] Article 8 of the Environmental Impact Assessment Directive (2011/92/EU).

10.2.2 Industrial Emissions Directive

The Industrial Emissions Directive (Directive 2010/75/EU) (hereafter 'IE Directive) aims to prevent and control pollution and emissions arising from industrial activities and installations by adopting an integrated approach to environmental protection.[122] The focus of the IE Directive is thereby not limited to the sole protection of either air, water, or land, but instead aims to prevent or reduce emissions and pollution within *and* between these environmental realms. The underlying thought is that improvements in one area of the environment may lead to detrimental effects in another.[130] By adopting such an integrated approach, the IE Directive aims to *"achieve a high level of protection of the environment as a whole"*.[148]

10.2.2.1 Industrial Activities within the Scope of the IE Directive

In order for an industrial activity to fall under the scope of the IE Directive, the activity needs to be referred to in Chapters II to VI of the Directive.[149] Of relevance to pilot projects and technologies under development is Article 2(2) of the IE Directive which states that: *"the Directive shall not apply to research activities, development activities or the testing of new products and processes".*

For power-to-gas installations, other than pilot or research sites such as the STORE&GO plants, which produce hydrogen and/or SNG, it needs to be assessed whether these activities fall under the scope of Chapter II. According to Article 10 of the IE Directive, Chapter II applies to those activities which are listed in Annex I. Table 10-2 below lists those activities within the power-to-gas chain which are covered by this Annex I.

Activity in PtG chain	**Reference in Annex I**
Hydrogen production through electrolysis	Entry 4.2 Production of inorganic chemicals, such as: a) gases, such as (…) hydrogen.
Production of substitute natural gas through methanation	Entry 4.1 Production of organic chemicals, such as: b) simple hydrocarbons (linear or cyclic, saturated or unsaturated, aliphatic or aromatic)
Re-electrification	Entry 1.1 Combustion of fuels in installations with a total rated thermal input of 50 MW or more

Table 10-2: Activities listed under Annex I relevant for power-to-gas

Entry 4 in Annex I titled "chemical industry", defines "production" as: *"production on an industrial scale by chemical or biological processing of substances or groups of substances listed in points 4.1 to 4.6."* As can be seen in Table 10-2, hydrogen and simple hydrocarbons such as methane are both included under these substances. Regarding the interpretation of the term "industrial scale", Annex I delegates a responsibility to the European Commission to provide guidance as to what is understood under this term. Such a guidance within the context of the IE Directive has, however, not yet been given. In absence of such guidance, an earlier interpretation of the term "industrial scale" in the context of the Directive concerning integrated pollution prevention and

[148] Article 1 of the Industrial Emissions Directive (2010/75/EU).

[149] Article 2(1) of the Industrial Emissions Directive (2010/75/EU). Chapter II deals with activities set out in Annex I; Chapter III prescribes special provisions for combustion plants; Chapter IV addresses waste (co-) incineration plants; Chapter V deals with installations and activities using organic solvents; and, Chapter VI sets out special provisions for installations producing titanium dioxide.

control (Directive 2008/1) (hereafter IPPC Directive) may provide some insight.[150] This guidance on the IPPC Directive, which is the predecessor of the IE Directive, states:

> *"Annex I Section 4 ("chemical industry") contains no quantitative capacity thresholds but only a reference to "production on an industrial scale". The scale of chemical manufacture can vary from a few grams of a highly specialised product to many tonnes of a bulk chemical product, yet both scales may correspond to "industrial scale" for that particular activity. If the activity is carried out for "commercial purposes", it should be considered as production on an industrial scale, even if the material is an intermediate product and therefore not itself traded".[138]*

As such, the crux of the matter is whether the chemical substances are produced for commercial purposes or not.

From the above it can be concluded that for power-to-gas facilities, not being regarded as research or development projects, the IE Directive applies to the production of both hydrogen and SNG, irrespective of the capacity. This conclusion is in line with an empirical study conducted by INERIS under six EU countries.[151] The study revealed that the majority of the countries under assessment consider hydrogen production through electrolysis as an activity falling under the IE Directive.[124]

10.2.2.2 Standards and Obligations for Power-to-Gas Installations and Applications

As set out in Table 10-3 below, the IE Directive is centred around several pillars which need to be taken into account by the national competent authorities during the authorisation of activities covered by the Directive.

Pillar	Description	Article(s)
Integrated approach to permits	• Member States need to ensure that no installations or combustion plant is operated without a permit. Permits conditions must take into consideration all environmental dimensions, e.g. emissions to air, water, soil, waste generation, and energy efficiency. • Permit applications are required to include a description of, among others, use of materials and substances, energy used and generated by the installation, nature and quantity of emissions, preventive measures, waste prevention measures, and main alternatives for proposed technologies, techniques and measures to prevent emissions;	Art. 4(1), 12 and 14
Best Available Techniques	• Member States, industry and other stakeholders are required to exchange information regarding best available techniques (BAT). Factors which need to be addressed include emissions, consumption and nature of materials, energy and water consumption, and waste generation. The information exchanged is compiled by the European Commission in order to draw up a 'BAT reference' document; • Subsequently, through a regulatory procedure, the European Commission adopts the conclusions of the BAT reference documents in a 'BAT conclusions' document; • Member States are required to ensure that the permit conditions are in line with these BAT conclusions. • Member States shall encourage the development and application of emerging technologies, especially those referred to in BAT reference documents.	Articles 11(b), 13, 14(3), 27 and Annex III

[150] Annex I to the IE Directive is for the most part copied from Annex I to the IPPC Directive. The IPPC Directive is the predecessor of the IE Directive.
[151] Austria, Belgium, Denmark, Germany, Great Britain, and the Netherlands.

Emission Limit Values	• Permit conditions need to contain at least emissions limit values for substances in Annex II;[152] • Permit under IE Directive shall not include emission limit values for carbon dioxide, as these are already covered under the emission trading scheme (Directive 2009/29/EC); • When the requirement to achieve emission levels associated with BAT leads to disproportional high costs in comparison to the environmental benefit obtained, authorities may set lower emission limit values; • Stricter norms than those included in the BAT conclusions may be imposed by the authorities where so required by other environmental quality standards.	Articles 14, 15 and 18
Public Participation	• Member States are required to allow the public early and effective opportunity to participate in the permit procedure. This includes timely notification and consultation; • Member States need to ensure that the public has access to a permit review procedure before a court of law or other independent body.	Articles 24 and 25

Table 10-3: Overview of Pillars within the IE Directive

It follows that power-to-gas installations of a non-research and development status are required to operate under a national permit regime which is open to public participation. How this regime may be streamlined with permit and environmental assessment requirements under other European legislation will be discussed under section 10.3.

Best Available Techniques (BAT) standards, *see* Table 10-3 above, can be relevant for power-to-gas technology under two scenarios. The first scenario concerns the situation that processes within the power-to-gas plant are covered under a BAT standard. For example, the BAT standard for "waste water and waste gas treatment/management systems in the chemical sector" may be of relevance.[125] This BAT standard applies to activities specified under section 4 "chemical industry" of Annex I of the IE Directive, including the production of hydrogen and methane. For such activities, the BAT document provides the best available techniques for water saving, waste water management, and pollutant recovery.

The second scenario under which BAT standards may be relevant for power-to-gas plants, is when processes or technologies within the power-to-gas chain themselves are considered to constitute the best available technique for a certain industry. To illustrate how such a scenario may play out in the future, it is interesting to consider the potential inclusion of hydrogen production through electrolysis under the BAT standard for "industrial emissions for iron and steel production", and the BAT document for "the refining of mineral oil and gas".[126][127] In both industries, hydrogen production through electrolysis can replace or benefit current processes.[153] For hydrogen production within the context of crude oil refinery, electrolysis can replace the currently considered BAT processes, namely partial oxidation and steam reforming. It needs to be emphasised however that at the current state of development of electrolyser technology, this technique will most likely not fall under the definition of "best available technique". The relative high CAPEX costs and

[152] Annex II makes reference to polluting substances in the domain of air and water pollution. Examples of air related substances are sulphur dioxide, nitrogen oxide, and dust including fine particulate matter. With regard to water pollution, the list includes metals and their compounds and particles in suspension.
[153] Different uses of green hydrogen within the process of steel protection will be explored within the H2FUTURE Horizon 2020 programme.

limited maximum capacity of electrolysers, as well as the limited implementation outside the research and development domain, stand in the way of considering this an “available technique”.[154]

10.2.3 Habitats Directive

Although the spatial footprint of power-to-gas plants is limited, the choice of location can be influenced through the working of the Habitats Directive (92/43/EEC). The Habitats Directive provides measures for the protection of both “special areas of conservation” and certain animal species. With regard to the special areas of conservation, the aim is to set up a coherent European ecological network of so called “Natura 2000” areas.[155] Projects which are intended to be located within a designated special area of conservation require prior approval by the competent authorities, but not before the general public has been offered a chance to respond. Approval must be based on an assessment which needs to establish *with certainty* that the project will not adversely affect the area.[156] If the assessment does reveal adverse effects, but there are important reasons for a project to be sited in a Natura 2000 area, the negative impact has to be compensated by expanding or improving habitat elsewhere.[157] Besides protecting certain areas, the Habitat Directive also protects certain animal and plant species listed under Annex IV. The animal species may not deliberately be killed, captured or disturbed.[158] Listed plants may not be picked, cut, or destroyed.[159] As will be discussed under section 10.3, when a parallel obligation to perform an impact assessment exists for a project developer under both the Habitats Directive and the IEA Directive, these assessments need to be streamlined by the competent authorities.

10.2.4 Water Consumption

The first step within the Power-to-gas process is the decomposition of a water molecule into hydrogen and oxygen. Water is thus an essential feedstock. Furthermore, water performs a cooling function during electrolysis and methanation. Although a calculation of the water footprint is part of the work of Deliverable 5.4 within the STORE&GO project on the environmental impact of power-to-gas plants, it has already been claimed by others that the water footprint does not exceed that of natural gas.[128] In comparison to the biomass based gases the footprint is even “marginal”.[128] With regard to the risk of pollution from the process/waste water, the engineering plans of the STORE&GO pilot plants indicate that no pre-treatment is required before the process/waste water can be drained into the sewage.

It is, therefore, not necessary to discuss European environmental law concerning the protection of water sources, e.g. the Water Framework Directive (2000/60/EC) which primary focus is on the protection of water quality.[130] Similarly, the absence of emissions in the process/waste water makes it unnecessary to provide a substantive analysis of the BAT standard document on water treatment in the chemical sector.

10.2.5 Environmental Liability Directive

When the operation of a power-to-gas installation results in environmental damage to protected species and habitats, water damage, or land damage, the operator of that installation may be held liable under the Environmental Liability Directive (Directive 2004/34/EC).[129] The Directive is an

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[154] Article 3(10)(b) of the Industrial Emissions Directive (2010/75/EU) defines ‘available techniques’ as: “those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member States in question, as long as they are reasonably accessible to the operator”.
[155] Article 3 of the Habitats Directive (92/43/EEC).
[156] Article 6 of the Habitats Directive (92/43/EEC).
[157] Article 6(3) and (4) of the Habitats Directive (92/43/EEC).
[158] Article 12 of the Habitats Directive (92/43/EEC).
[159] Article 13 of the Habitats Directive (92/43/EEC).

expression of the principle that the polluter should pay.[160] The prospective for operators to be held liable for environmental damages aims to have a precautionary and preventive effect.[130] For activities which are required to operate under a permit in accordance with the IE Directive, among which power-to-gas installations, the Environmental Liability Directive imposes a strict liability regime.[161] Under such a strict liability regime, the question of fault is irrelevant. Instead, liability simply exists when damage occurs.

Besides the establishment of a liability regime in the event of environmental damage, the Directive also obliges operators to take the necessary preventive measures where there exists an imminent threat for damage.[162] Where such preventive measures appear insufficient, and environmental damage nevertheless materialises, operators have to inform the competent authorities without delay, take all practical steps to contain or remove the source of the damage, and take other reasonable remedial actions.[163] Similar required actions in the event of incidents or accident are also required by the IE Directive.[164]

10.3 European Legislation on Chemicals and Safety

As will be clear form the analysis under this section on European legislation related to chemicals and safety, hydrogen and SNG are regarded as hazardous chemicals. This not only has as a consequence that operators of power-to-gas installations themselves have to conform in their plant design and operating procedures with safety standards, they also have to ensure that downstream users have access to information on the (hazardous) characteristics of the SNG supplied. This section will first, under 10.2.1 and 10.2.2 discuss which requirements for the labelling, packaging, and putting on the market of SNG flow from EU chemicals legislation. Subsequently, under 10.2.3, will discuss safety requirements for power-to-gas installations which are prescribed under the Seveso III Directive.

10.3.1 Regulation on the Classification, labelling and Packaging of Substances and Mixtures (‘CLP Regulation’)

European legislation on chemical substances aims to find a balance between a high level of protection of human health and the environment, and furthering the free movement of substances.[165] The first important piece of EU legislation in this regard is the “Regulation for Classification, Labelling and Packaging of Substances and Mixtures”, or, in short, “CLP Regulation” (No 1272/2008).[131] This Regulation incorporates the United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS). The CLP Regulation harmonises the criteria for classifying a substance as “hazardous”, and the rules for standardised labelling and packaging of such substances.[166] It thereby aims to ensure that potential hazards associated with certain chemicals are communicated to exposed workers and consumers.

Manufacturers of substances are required to correctly classify, label and package substances before placing them on the market.[167] Notwithstanding certain exemptions, this is a “self-

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[160] Recital 18 of the Environmental Liability Directive (2004/34/EC).
[161] Article 3(1) and Annex III of the Environmental Liability Directive (2004/34/EC) and Case C-378/08 *ERG and others* [2010], ECR I-1919.
[162] Article 5(1) of the Environmental Liability Directive (2004/34/EC).
[163] Articles 6 and 7 and Annex II of the Environmental Liability Directive (2004/34/EC).
[164] Article 7 of the Industrial Emissions Directive (2010/75/EU).
[165] Article 1 of the CLP Regulation (EC) No 1272/2008 and Article 1(1) REACH Regulation (EC) No 1907/2006.
[166] Article 1(a) of the CLP Regulation (EC) No 1272/2008.
[167] Article 4(1) of the CLP Regulation (EC) No 1272/2008.

classification" system whereby the responsibility of correct classification is left to the manufacturer itself. Non-compliance, however, results in a prohibition to place the substance on the market.[168]

Starting point for the classification, labelling and packaging of substances is the correct identification thereof. The concept of "substances" in the CLP Directive is defined as "*a chemical element and its compounds in the natural state or obtained by any manufacturing process, including (…) any impurity deriving from the process used (…)".*[169] When the typical content of the main constituent is at least 80% (w/w), the substance is considered to be a "well defined mono-constituent substance" and should be identified by reference to the chemical name of the main constituent.[133]) The other constituents which are derived from the production process, and which are not intentionally added, are to be regarded as impurities. However, as the general rule is that where possible information should be available on 100 percent of the components present, the impurities with a share of 1 percent or more also need to be specified.[133]

Although the power-to-gas pilot plants within the STORE&GO project were not yet operational at the moment of the publication of this Deliverable, the chemical composition of SNG from similar processes has already been reviewed.[4] According to this review, SNG produced through catalytic or biological methanation processes will, similar to non-synthetic natural gas, contain at least 80% methane (CH_4). SNG can therefore be considered to be a mono-constituent substance which should be identified by reference to the main constituent, being methane. Methane is already covered under the lists of substances of which the classification and labelling is harmonised under the CLP Directive.[170] The classification and labelling specifications of SNG is provided in Table 10-4 below.

Identifier	Methane
Index No	601-001-00-4
Name and mol. formula	Methane CH_4
EC No	200-812-7
CAS No	74-82-8
Classification	

168 Article 4(10) of the CLP Regulation (EC) No 1272/208. Although not discussed in this deliverable, importers and downstream users also have the responsibility to correctly classify, label, and package substances before placing them on the market.
169 Article 2(7) CLP Regulation (EC) No 1272/2008.
170 Part 3 of Annex VI of the CLP Regulation (EC) No 1272/2008.

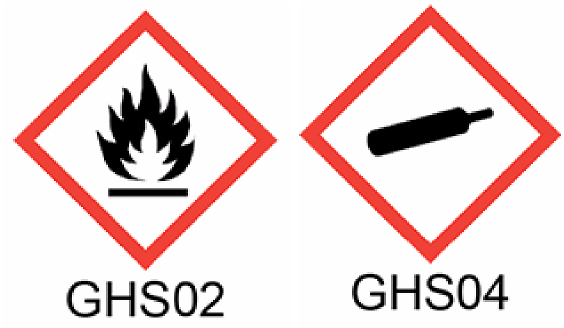
Hazard Class and category code(s)	Flammable Gas 1 H220[171] Pressurised Gas H280
Labelling	
Pictogram	
Signal word(s)	Danger
Hazard Statement Code(s)	H220: extremely flammable gas
Notes	When put on the market gases have to be classified as 'Gases under pressure'

Table 10-4: Classification of methane under the CLP Regulation

10.3.2 Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals ('REACH Regulation')

Another important legislative instrument in the domain of European chemical regulation is the "Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals" (No 1907/2006), commonly referred to as the "REACH regulation".[132] This Regulation requires actors in the private sectors (i.e. manufacturers and importers of chemicals) to generate data regarding the intrinsic properties of certain chemical substances, including SNG, and to subsequently register those substances with the European Chemicals Agency (ECHA). This data has to be disclosed throughout the supply chain and to employees. Under the "no data, no market" principle, a substance subject to REACH on which no data has been submitted is not eligible to be sold within the EU. Based on the data submitted, the ECHA or European Commission can ban or limit the distribution and use of certain high risk chemicals.

10.3.2.1 Substances and Exemptions under the scope of REACH

The REACH Regulation aims to balance between i) the protection of human health and the environment, and ii) facilitating trade of chemical substances within the internal market while enhancing competitiveness and innovation.[134] Where a too lenient system on the registration, evaluation, and authorisation of chemicals could be detrimental to the achievement of the first objective, a too rigid system can incur unnecessary high costs and administrative burdens for manufacturers, importers and suppliers. Therefore, in order to come to a balance between the protective and economic objectives, a wide scope is combined with exemptions for certain substances.

Similar to the CLP Regulation, the starting point for the scope of application of REACH is the broad concept of "substances", which includes SNG.[172] Of relevance to small-scale power-to-gas projects

[171] Category 1 Flammable gases are gases which at 20 °C and a standard pressure of 101.3 kPa: a) are ignitable when in a mixture of 13% or less by volume in air; or b) have a flammable range with air of at least 12 percentage point regardless of the lower flammable limit. *See* point 2.2.2.1 of Annex I to the CLP Regulation (EC) No 1272/2008.

is that the duty for registration only exists for substances that are manufactured or imported in volumes of 1 tonne or more per year.[173] For pilot plants which exceed this threshold, Article 9(1) allows for an exemption from registration for a period of five years, if this takes place for product and process orientated research and development (PPORD).[135] A condition is that the project contributes to the scientific development of a substance, including the scaling-up or improvement of a production process.[135] In order to benefit from such an exemption, the manufacturer has to submit a notification to the ECHA.[174] Furthermore, this exemption does not relieve a manufacturer from its obligations under the CLP Regulation.

Besides exemptions for research and development purposes, the REACH Regulation also provides for other whole and partial exemptions from registration for a variety of reasons.[134] Substances included under Annex IV, such as carbon dioxide, are exempted as already sufficient information is available on the listed substances. Based on the available information on the intrinsic properties of these substances, it is determined that these cause minimum risks. Substances covered by Annex V, including hydrogen and natural gas, are exempted because registration is deemed inappropriate or unnecessary for these substances. Table 10-5 below provides an overview of exempted substances which are, directly or indirectly, relevant to power-to-gas.

Substance	Article	Scope of Exemption
Hydrogen	Article 2(7)(b) and Annex V, entry 13	Titles II (registration), V (downstream users) and VI (evaluation)
Oxygen	Article 2(7)(b) and Annex V, entry 13	Titles II (registration), V (downstream users) and VI (evaluation)
Carbon Dioxide	Article 2(7)(a) and Annex IV	Titles II (registration), V (downstream users) and VI (evaluation)
Raw and processed Natural Gas	Article 2(7)(b) and Annex V, entry 7	Titles II (registration), V (downstream users) and VI (evaluation)
Biogas	Article 2(7)(b) and Annex V, entry 12	Titles II (registration), V (downstream users) and VI (evaluation)

Table 10-5: Partial exemptions under REACH

As SNG is not explicitly mentioned, it needs to be reviewed whether the gas can be categorised under one of the already exempted substances listed in Table 10-5. For SNG to fall under the exemption for natural gas, it must be considered to constitute a *"not chemically modified substance occurring in nature"*.[175] According to the ECHA guidance document for Annex V exemptions, a substance must therefore fulfil both the criteria of "a substance occurring in nature", a term defined under Article 3(39) of the REACH Regulation, and "not chemically modified", which is defined under Article 3(40).[136][176] Article 3(39) defines "substances which occur in nature" as naturally

[172] Article 3(1) of the REACH Regulation (EC) No 1907/2006 defines "substances" as: "a chemical element and its compounds in the natural state or obtained by any manufacturing process, including any additive necessary to preserve its stability and any impurity deriving from the process used, but excluding any solvent which may be separated without affecting the stability of the substance or changing its composition"

[173] Article 6 of the REACH Regulation (EC) No 1907/2006.

[174] Article 9(2) of the REACH Regulation (EC) No 1907/2006.

[175] Annex V, entry 7 of the REACH Regulation (EC) No 1907/2006.

[176] ECHA, Guidance for Annex V Exemptions from the Obligation to Register, pp. 20.

occurring substances as such, which are unprocessed, or processed by only physical means.[177] The term "not chemically modified" is defined under Article 3(40) as: *"a substance whose chemical structure remains unchanged, even if it has undergone a chemical process or treatment, or a physical mineralogical transformation, for instance to remove impurities"*. Of special relevance to synthetic gases, such as SNG, is the statement in the guidance document that the exemption for substances under Annex V entry 7 does *not* apply to the synthetic versions of these substances. As reason is provided that these synthetic versions do not comply with the criteria "occurring in nature".[178] The document thereby adds that only methane processed from raw natural gas is regarded as natural gas, and methane produced from non-fossil sources is not.[179] Thus although SNG consists (largely) out of the same constituents as natural gas, under the REACH Regulation, both substances are awarded different treatment.

It can be concluded from the above that registration is required for the production and placing on the market of SNG in quantities of one tonne or more per year and not produced for the purpose of product and process orientated research and development. It would, however, be recommendable that a similar exemption is awarded for SNG under REACH, as is the case for gases of a similar chemical composition such as natural gas and biogas. It should be emphasised that even in the event an exemption would be introduced in the future, this does not relieve a substance from the requirements under the CLP Regulation.

10.3.2.2 Stages of Registration, Evaluation, and Authorisation

The acronym 'REACH' stands for Registration, Evaluation and Authorisation of Chemicals, hinting to the three possible stages a chemical substance has to go through before being allowed to be marketed. The authorisation stage, based on which substances can be banned or restricted, will not be discussed here, as it can be assumed that this will not be relevant for the manufacturing, placing on the market, or usage of SNG. Authorisation is required for *"substances of probable serious effects to human health or the environment giving rise to very high concern"*.[180] The first argument on which this assumption is based is that none of the substances within the power-to-gas production chain are currently considered to be "substances of very high concern" under the REACH Regulation.[181] As a second argument, SNG shares similar characteristics with natural gas, methane, and biomethane, which are already traded within the internal market without restrictions.

The central principle and duty within the REACH Regulation, as laid down in Article 1(3), is that producers, importers, and downstream users of substances are required to ensure that the substances they manufacture, place on the market, or use, do not adversely affect human health or the environment. It goes well beyond the scope of this Deliverable to give a complete overview of all requirements for all actors in the supply chain. Therefore, the focus is limited to obligations imposed on the manufacturer of a substance, in this context the operators of the STORE&GO pilot sites.

Article 5, titled "no data, no market", when read together with Article 6, states that no substances in quantities of one tonne or more per year shall be manufactured or be placed on the European

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[177] The means for processing mentioned in Article 3(39) REACH are: manual, mechanical or gravitational means, by dissolution in water, by flotation, by extraction with water, by steam distillation or by heating solely to remove water, or which is extracted from air by any means.

[178] ECHA, Guidance for Annex V Exemptions from the Obligation to Register, pp. 20-21.

[179] ECHA, Guidance for Annex V Exemptions from the Obligation to Register, p. 25.

[180] Articles 57 and 59 of the REACH Regulation (EC) No 1907/2006.

[181] "Substances of very high concern" are those listed under Annex I, XIII and XIV. Annex I relates to substances which are considered to be carcinogenic, mutagenic, or toxic for reproduction. Annex XIII lists criteria in order to determine whether substances are considered to be persistent, bioaccumulative an toxic (or very persistent and very bioaccumulative). Annex XIV gives a list of substances which are banned from usage within the EU without specific authorisation.

internal market without prior registration with the ECHA. Registration involves the submission of the gathered data on the chemical substance by the manufacturer to the ECHA in the form of a technical dossier.[182] Information which has to submitted includes information on manufacture and use(s) of a substance[183], information on classification and labelling in accordance with the CLP Regulation[184], and guidance on safe use[185]. As a basic rule, the more of a substance is manufactured or imported, the more information is required to be submitted. A final note with regard to the registration procedure is that under the "one substance, one registration principle", the joint registration of a substance by multiple manufacturers is allowed.

Subsequent to the registration procedure follows the evaluation procedure. A first step therein is the carrying out of a dossier evaluation, or completeness check by the ECHA. This is a non-qualitative exercise whereby the ECHA only checks if the submitted information is complete.[186] Optionally, the ECHA and Member States authorities can conduct tests to determine whether, and on which grounds, a substance constitutes a risk to human health or the environment.[134]

10.3.2.3 Information within the Supply Chain

The means through which REACH aims to fulfil its objective is the central gathering of data on chemical substances and the disclosure of this data throughout the whole supply chain to suppliers, buyers, and, eventually, downstream users which handle the substances.[132][134] This line of communication on the appropriate risks and safety measures is not, however, one directional. Downstream users have an equally important role to fulfil by sending information back in the upstream direction on matters such as by who, and how, substances are used. This allows the supplier to update the information it has to provide in accordance with exposure scenarios and intended usage of the substance.

To this end, the REACH regulation requires suppliers, including manufacturers, to provide a safety data sheet to the recipient of an hazardous substance.[187] The content and format requirements for the safety data sheet are provided for in Annex II to the REACH Regulation. In broad terms, the documents must provide information on the identity, hazards, risks, and appropriate safety measures associated with the use of the substance.

10.3.3 Seveso III Directive

The so-called "Seveso III" Directive (2012/18/EU) prescribes measures for the prevention of major industrial accidents and the limitation of the consequences thereof for human health and the environment.[137] The Directive has been named after the Italian town of Seveso, in which in 1976 a severe dioxin disaster took place. The Seveso III Directive was preceded by Seveso I and II.

10.3.3.1 Industrial Activities under the Scope of the Directive

The Seveso III Directive applies to those establishments in which certain dangerous substances are produced, used, handled or stored.[188] The term "establishment" refers to the whole location under control of an operator where dangerous substances are present, and may include multiple installations and related infrastructure.[189] Those substances or mixtures which are regarded as dangerous for the purpose of this Directive are listed under Annex 1 to the Directive.[190] The

[182] Article 10(a) of the REACH Regulation (EC) No 1907/2006.
[183] Article 10(a)(iii) and section 3 of Annex VI of the REACH Regulation (EC) No 1907/2006.
[184] Article 10(a)(iv) and section 4 of Annex VI of the REACH Regulation (EC) No 1907/2006.
[185] Article 10(a)(v) and section 5 of Annex VI of the REACH Regulation (EC) No 1907/2006.
[186] Article 41 of the REACH Regulation (EC) No 1907/2006.
[187] Article 31(1) of the REACH Regulation (EC) No 1907/2006.
[188] Article 2(1) of the Seveso III Directive (2012/18/EU).
[189] Article 3(1) of the Seveso III Directive (2012/18/EU).
[190] Article 3(10) of the Seveso III Directive (2012/18/EU).

classification of dangerous substances under Annex I is in accordance with the CLP Regulation. As to the nature of the presence of the substances, the Directive is indifferent whether this is in the form of a raw material, product, by-product, residue, or intermediate.[191] The Directive does not apply to the transportation of dangerous substances through pipelines outside the establishment.[192]

With regard to required safety measures by operators, the Directive makes a distinction between “lower-tier” and “upper-tier” establishments, based on the quantities present of a certain dangerous substance.[193] As will be discussed below, the required preventive measures for upper-tier establishments’ are more stringent than for those establishments operating within the lower-tier.

Substance	Lower-tier [tonnes]	Upper-tier [tonnes]	Reference
Hydrogen	5	50	Annex I part 2 entry 15
Substitute natural gas/ methane	10	50	Annex 1 part 1 entry P2 ‘Flammable gases’

Table 10-6: Thresholds for dangerous substances under the Seveso III Directive

10.3.3.2 Requirements for Operators of Power-to-Gas Plants under the Seveso III Directive

As a general obligation, Member States need to ensure that an operator of an establishment falling under the scope of the Directive takes all necessary measures to prevent major accidents, and takes measures to limit the consequences of accidents for human health and the environment.[194] More concrete, the Directive requires Member States to ensure that operators:

I. Notification: sending of a notification to the national competent authority containing, among others:

- information sufficient to identify the dangerous substances and category of substances involved or likely present;
- quantity and physical form of the dangerous substance or substances concerned;
- the activity or proposed activity of the installation or storage activity;
- the immediate environment of the establishment, and factors likely to cause a major accident or to aggravate the consequences thereof.[195]

II. Major-accident prevention policy: drawing up of a document in writing setting out the major-accident prevention policy (MAPP). It shall include:

- operator’s overall aims and principles of action;
- role and responsibility of management;
- commitments towards continuously improving the control of major-accident hazards;
- commitments towards ensuring a high level of protection.[196]

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[191] Article 3(10) of the Seveso III Directive (2012/18/EU).
[192] Article 2(d) of the Seveso III Directive (2012/18/EU).
[193] Article 3(2) and (3) of the Seveso III Directive (2012/18/EU).
[194] Article 5(1) of the Seveso III Directive (2012/18/EU).
[195] Article 7(1)(a-g) of the Seveso III Directive (2012/18/EU).
[196] Article 8 (1) of the Seveso III Directive (2012/18/EU).

III. Safety report and emergency plans by upper-tier establishments: production of a safety report by upper-tier establishments for the purpose of, among others:

- demonstrating that a MAPP and a safety management system for implementing it have been put into effect;
- identifying major-accident hazards and scenarios and demonstrating that preventing measures have been taken;
- demonstrating that safety and reliability have been taken into account in the design, operation and maintenance of any installation, storage facility, equipment and infrastructure which are linked to the hazards identified;
- demonstrating that internal emergency plans have been drawn up and providing information enabling the drawing up of external emergency plans;
- providing information to the competent authority for decision-making in relation to the siting of future activities within the vicinity of the establishment.[197]

IV. Supply of information and course of action following a major accident: providing as soon as practicable after a major accident to the competent authority:

- notification of the accident to the competent authorities as to: circumstances, dangerous substances involved, data available for assessing effects on human health, the environment and property, and measures taken;
- information on medium- and long-term mitigating measures;
- measures preventing recurrence of such an accident.[198]

In the event that an operator has refrained from adhering to the above listed requirements, a Member State has the discretion to prohibit the use or bringing into use of the establishment, or any part thereof.[199] However, where the measures taken by the operator for the prevention and mitigation of major accidents are seriously deficient, the Member States shall prohibit the use, or bringing into use, of the establishment, or any part thereof.[200]

10.3.3.3 Influence of Seveso III on the Location of Power-to-Gas Plants

Besides the requirements above, the Seveso III Directive requires Member States to take the risks for major accidents into account in their land-use policies.[201] More precisely, the Directive prescribes that Member States, when deciding on the siting of new establishments, shall take account of the need to maintain appropriate distance between the establishment and the build environment and/or natural areas which are of particular sensitivity or interest.[202] Operators of relevant establishments are required to provide the competent and planning authority with information on the risks of the establishment. As will be discussed in the next section, Member States are allowed to streamline requirements under the Seveso III Directive in the administrative procedure with similar requirements under other Directives.[203]

10.4 Streamlining of Administrative Procedures

From the review above on the applicable European environmental and safety legislation, it follows that a developer and operator of a power-to-gas installation is likely to have various assessment

[197] Article 10 of the Seveso III Directive (2012/18/EU). Drawing up of internal and external emergency plans is addressed under Article 12.
[198] Article 16 of the Seveso III Directive (2012/18/EU). Articles 17 and 18 prescribe the necessary actions by the competent authority and Members States following a major accident.
[199] Article 19(1) paragraph 2 of the Seveso III Directive (2012/18/EU).
[200] Article 19(1) paragraph 1 of the Seveso III Directive (2012/18/EU).
[201] Article 13 (1) of the Seveso III Directive (2012/18/EU).
[202] Article 13(1) and (2) of the Seveso III Directive (2012/18/EU).
[203] Article 13(4) of the Seveso III Directive (2012/18/EU).

and reporting obligations. Such accumulation of assessment, information, and permit requirements constitutes a considerable administrative burden for projects. Already in 2000, the European Commission described administrative and planning procedures as a "major barrier" to the development of renewable energy production.[139] As a remedy to lighten this burden, the Commission allows Member States to set up coordinated or joint procedures for projects which have overlapping obligations under different legislations.[204] Under a joint procedure, a single integrated assessment is sufficient for compliance with simultaneous obligations. Under a coordinated procedure, it remains required to execute multiple individual assessments. However, Member States may then designate a coordinating authority which streamlines the various assessment procedures.[140]

The discretion for Member States to organise joint or coordinated procedures may differ for various combinations of assessments. Where both an assessment under the EIA Directive and under the Habitat Directive is required, Member States are *obligated* to set up joint or coordinated procedures.[205] When, however, there is an accumulation of assessment requirements under the EIA Directive and other instruments, the Member States *may* set up such procedures.[140] This is for example the case where the obligation to perform an assessment under the EIA Directive collides with similar obligations under the IE Directive and/or Seveso III Directive.[206]

The necessity to relieve the administrative burden for renewable energy related projects in particular, is addressed under the 2009 Renewable Energy Directive. Member States are required, among others, to streamline administrative procedures and develop simplified and less burdensome procedures for smaller projects.[207] The list of project categories which are to profit from such beneficial treatment does, however, not make reference to power-to-gas related technologies or processes. Instead, the list of activities is limited to *"plants and associated transmission and distribution network infrastructures for the production of electricity, heating or cooling from renewable energy sources, and to the process of transformation of biomass into biofuels or other energy products."*[208] Accordingly, Member States are not obligated to streamline the administrative procedures for power-to-gas projects in a similar way as for other renewable energy projects.

As, in the eyes of the European Commission, national administrative procedures still involve to many different authorities, the Recast Renewable Energy Directive includes a so called "one stop shop" obligation for the Member States.[209] What this means is that Member States need to set up one administrative contact point which coordinates the whole authorisation procedure. Furthermore, this permit procedure may not exceed a period of three years.[210] The type of activities to which this obligation applies are plants, including associated transmission and distribution network infrastructures, for the *production* of energy from renewable energy sources. Arguably, this includes power-to-gas plants. It would be recommended to extend the scope to include energy storage projects.

[204] Article 2(3) of the Environmental Impact Assessment Directive (2011/92/EU).
[205] Article 2(3) first paragraph of the Environmental Impact Assessment Directive (2011/92/EU).
[206] Article 13(4) of the Seveso III Directive 2012/18/EU and Article 12(2) of the Industrial Emissions Directive (Directive 2010/75/EU).
[207] Article 13(1) of the Renewable Energy Directive (2009/28/EC).
[208] Article 13(1) of the Renewable Energy Directive (2009/28/EC).
[209] Artice 16(1) of the Recast Renewable Energy Directive (COM(2016) 767 final/2).
[210] Article 16(4) of the Recast Renewable Energy Directive. (COM(2016) 767 final/2)

11 Conclusions

This Deliverable under the scope of the STORE&GO project has attempted to provide an overview of EU legislation applicable to power-to-gas. In absence of specific rules or legal guidance documents on power-to-gas, the conclusions drawn in this Deliverable are often derived from interpretation. These conclusions not only invite the EU legislator to think about specific legislation on power-to-gas, but also invite stakeholders and researchers to join the legal debate on power-to-gas. The absence of literature on European law applicable to power-to-gas is illustrative of the need to intensify this debate. To that end, this Deliverable is also intended to kick-start a dialogue.

Based on the research and discussion presented in this Deliverable, the following key findings can be presented:

1. **Necessity to align definitions and ownership regimes for power-to-gas under EU electricity and gas legislation**

Power-to-gas is likely to be covered under the proposed definition and ownership regime for energy storage under the Recast Electricity Directive, also when the stored energy is not reconverted into electricity but discharged as a gas. However, the conversion of electricity to a gas, which can also be considered a gas production activity, and the subsequent storage thereof, is also regulated under the 2009 Gas Directive. Ambiguities remain on how these definitions and ownership regimes align. In the first place, it needs to be clarified to what extent power-to-gas is both an energy storage and gas production activity. Second, it needs to be clarified how the conditional ownership and operation of a Power-to-gas energy storage facility by a network system operator under the Recast Electricity Directive aligns with the prohibition for such operators to perform production activities under the 2009 Gas Directive. Third, it needs to be clarified to what extent gas storage system operators are allowed to operate a power-to-gas energy storage facility when this could also be considered a gas production activity. It would thus be required that the EU legislator explicitly prescribes to what extent the proposed legal framework on energy storage applicable to power-to-gas takes precedence over similar rules under the 2009 Gas Directive. In the future, a single Directive covering both the internal market for gas and electricity may reflect the increasing sectoral integration in the energy sector.

2. **Need for continued efforts to harmonise gas quality standards**

Gas quality harmonisation efforts under the umbrella of the European Committee for Standardisation have not resulted in consensus on a common Wobbe Index or hydrogen limit. In absence of such harmonised standards, the heterogeneous parameters of the Member States remain in place. When such parameters are (too) stringent or differ between two Member States, this may hamper the injection of alternative and more sustainable gases to the natural gas system and the cross-border trade therein.

3. **Need to clarify the position of substitute natural gas under the Renewable Energy Directive**

The three STORE&GO pilot sites all produce a gas by, in a first stage, producing hydrogen from renewable electricity and, in a second stage, synthesising this hydrogen with a carbon source, which can be of a fossil, biogenic, or ambient source. The output gas is commonly known as synthetic, or substitute, natural gas (SNG). Although a 2015 amendment to the Renewable Energy Directive has introduced the term "*renewable liquid and gaseous transport fuels of non-biological origin*" which may cover SNG, this only applies to transport. As SNG can also be used in other sectors such as heating/cooling or electricity production, it should be assessed whether this term should be expanded to cover other sectors as well. Furthermore, although it will be argued in this Deliverable that the Renewable Energy Directive is unbiased towards the carbon source used for methanation, and that the sustainability criteria for biomass do not apply to biogenic carbon sources, legal certainty would require that these matters are explicitly addressed.

4. Need for harmonised rules on network tariffs for energy storage and power-to-gas

An often mentioned financial barrier for energy storage technologies, including power-to-gas, are the network tariffs which need to be paid double as both consumer (of electricity during charging) and producer (during discharging). The recently proposed Recast Electricity Directive allows the European Commission to adopt specific guidelines for network tariff for energy storage. This would allow for a specific tarification regime that recognises the contribution of energy storage and power-to-gas to decarbonisation and security of supply, in the same spirit as the recently adopted tariff regime for gas storage facilities.

5. Need for guidance with regard to financial (dis)incentives for power-to-gas

The guidelines on state aid for environmental protection and energy 2014-2020 provide guidance on the legality of support schemes for renewable energy such a biogas production. However, no attention has (yet) been awarded to power-to-gas or energy storage projects. Similarly, the sections in the guideline on exemptions for energy intensive industry for green surcharges make no explicit reference to such activities. The adoption of specific rules may guide Member States in their design of financial incentives for power-to-gas projects.

6. Need to clarify the position of fossil Carbon Capture and Storage (CCU) under the EU emission trading scheme

Although the STORE&GO sites all use biogenic or ambient carbon for methanation, another possible carbon source is fossil carbon captured at end-point. Clarification is required on the issue whether the capture and transfer of fossil CO_2 for CCU, for example as feedstock for SNG, needs to be covered by allowances under the EU emission trading scheme. More specifically, the question is whether CCU for the production of fuels is covered by the phrase "*permanently stored or avoided"* under the EU emission trading scheme for the post-2020 era.

7. Necessity to develop harmonised rules on guarantees of origin which take account of the need for seasonal storage

A system for guarantees of origin harmonised at the EU level could provide detailed rules on, amongst others, how guarantees of origin for different forms of energy (e.g. electricity and gas) interact when one form of energy is converted into another. Furthermore, looking at the rules on guarantees of origin as proposed under the Recast Renewable Energy Directive, the proposed shortened lifespan of guarantees of origins needs to be reconsidered as this may disincentive the long-term storage of renewable energy.

8. Need to clarify on the applicability of EU environmental legislation

Hydrogen and SNG are chemicals of which the production, including the construction and operation of a power-to-gas plant, is regulated under EU legislation related to the protection of the environment and human health. As, however, the relevant legislative instruments contain no direct reference to power-to-gas, their applicability remains partially open to interpretation. For example, it cannot be determined with certainty whether the obligation to perform an environmental impact assessment flows automatically from its status as Annex I project under the Environmental Impact Assessment, or may be left to the discretion of the Member States as is the case for Annex II projects.

9. Need to consider an exemption for SNG for registration under the REACH Regulation

Producers of SNG have to comply with the registration requirements for chemical substances under the REACH Regulation. However, substances with similar characteristics are exempted from such an obligation. This is for example the case for natural gas and biogas, but also for the substance which are used as a feedstock for SNG: hydrogen and CO_2. It may thus be appropriate to consider a similar exemption for SNG for registration under the REACH Regulation.

10. Need to consider to include energy storage and power-to-gas under the streamlined and simplified administrative procedures under the Recast Renewable Energy Directive

Although the “one stop one shop” requirement for the permitting process of renewable energy projects is a positive development, energy storage and power-to-gas are not explicitly included.

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