Interreg North Sea Region: HyTrEc2

Deliverable 3.5: Hydrogen Transport Legislation and Standards in the NSR: Interim Report

Project Number 38-2-11-16

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Lowering your emissions through innovation in transport and energy infrastructure

PROJECT

REPORT

Deliverable 3.5: Hydrogen Transport Legislation and standards in the NSR:

Interreg North Sea Region: HyTrEc2
(Project Number 38-2-11-16)

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Contents

Abbreviations

Abbreviation	Description	Abbreviation	Description
ADN	European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways	ILUC	Indirect Land Use Chane
ADR/RID	European Agreement Concerning the International Carriage of Dangerous Goods by Road	IMDG	International Maritime Dangerous Goods
AFID	Alternative Fuels Infrastructure Directive	ISO	International Organization for Standardisation
APEA	Association of Petroleum and Explosives Administration	KBA	Kraftfahrtbundesamt (Federal Motor Transport Authority)
ATEX	Atmospheres Explosible	kg	Kilogram
BEVs	Battery Electric Vehicles	KOH	Potassium hydroxide
BIGHIT	Project in Orkney to demonstrate an integrated model of H2 production, storage, transportation and utilisation for heat, power, and mobility.	KVI	Keur Voor Inbedrijfname (Certification for Commissioning)
BRZO	Besluit Risico's Zware Ongevallen (Dutch Major Accidents Decree)	KVI	Keur Voor Inbedrijfname (Certification for Commissioning)
CAA	Civil Aviation Authority	LFL	Lower Flammability Limit
CCSU	Carbon Capture Storage and Use	MARPOL	Maritime Pollution
CCVB	Closing Continuing Calibration Verification	MetroHyVe	Project with the aim of ensuring measurement challenges are not the barrier preventing the global uptake of H2 vehicles.
CE	Conformité Européene (European Conformity)	MIA	Milieu-investeringsaftrek (Environmental Investment Allowance)
CEN	Comité Européen de Normalisation (European Committee for Standardisation)	MSB	Myndigheten för Samhällsskydd Och Beredskap (Swedish Civil Contingencies Agency)
CH_4	Methane	NIP	National H2 and Fuel Cell Technology Innovation Programme
CHP	Combined Heat and Power	NOBO	Notified body
CLP	Classification, Labelling and Packaging	NSC	North Sea Commission
CO_2	Carbon Dioxide	NSR	North Sea Region
COMAH	Control of Major Accident Hazards	P2G	Power-to-Gas
DIS	Draft International Standard	PD	Published Document

Abbreviation	Description	Abbreviation	Description
DIV	Dienst voor Inschrijving van Voertuigen (Vehicle Registration Service)	PED	Pressure Equipment Directive
DoD	Department of Defence	PEM	Proton Exchange Membrane/Polymer Electrolyte Membrane
DPHFCs	Danish Partnership for H2 and Fuel Cells	PPC	Pollution Prevention and Control Legislations
DSB	Norwegian Directorate for Civil Protection	PTFE	Polytetrafluoroethylene
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations	R&D	Research and Development
DVSA	Driver & Vehicles Standards Agency	RCS	Regulations, Codes and Standards
EC	European Commission	RDW	Road Safety Directorate
ECE	Economic Commission for Europe	REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
ECWVTA	European Community Whole Vehicle Type Approval	RED	Renewable Energy Directive
EIA	Environmental Impact Assessment	RED II	The Revised Renewable Energy Directive
EIGA	European Industrial Gases Association	RID	Standards concerning the International Carriage of Dangerous Goods by Rail
EN	European Norm	SAE	Society of Automotive Engineers
EU	European Union	SAT	Statlige Planretningslinjer for Samordnet olig–, Areal– og Transportplanlegging (National Guidelines for Sustainable and Coordinated Housing, Spatial and Transport Planning)
FC	Fuel Cell	SDS	Safety Data Sheet
FCEV(s)	Fuel cell electric vehicle(s)	SEA	Strategic Environmental Assessment
FQD	Fuel Quality Directive	SEVESO	Main EU legislation dealing specifically with the control of onshore major accident hazards involving dangerous substances
GDPR	General Data Protection Regulations	sf	Safety Factor
GHG(s)	Greenhouse Gas(es)	SF	Ratio between burst pressure and nominal fill pressure.
GTR	Global Technical Regulation	SMR	Steam Methane Reforming
GVW	Gross Vehicle Weight	SOLAS	Safety of Life at Sea
H_2	H2	SPAs	Special Protection Areas
H2FC	H2 Fuel Cell	SPW	Service Publique de Wallonie (Public Service of Wallonia)
H2ME	Is a flagship project giving fuel cell electric vehicle drivers access to the first truly pan-European network of H2 refuelling stations.	SRG	Safety Standards Group

Abbreviation	Description	Abbreviation	Description
HRS(s)	H2 Refuelling Station(s)	t	Tonne
HSE	Health, Safety & Environment	TDG	Transport of Dangerous Goods
HyFive	Project to deploy 110 FCEVs across Europe.	TEN-T	Transnational European networks for transport
HyLaw	H2 Law and removal of legal barriers to the deployment of fuel cells and H2 applications.	TPED	Transportable Pressure Equipment Directive
HySafe	Project looking into the Safety of H2 as an Energy Carrier.	TS	Technical Specification
HyTrEc	H2 Transport Economy (Project)	TÜV	Technischer Überwachungsverein (Technical Inspection Association)
HyTrEc2	Successor of the H2 Transport Economy Project.	UFL	Upper Flamabality Limit
ICAO	International Civil Aviation Organization	UN	United Nations
ICE	Internal Combustion Engine	UNECE	United Nations Economic Commission for Europe
		VCA	Vehicle Certification Agency
IEA	International Energy Agency	VVFS	Vägverkets Föreskrifter (Swedish Road Traffic Agency Legislations)
IGC	Industrial Gases Council	VVM	Danish Environmental Impact Assessment
IHK	Industrie- und Handelskammer (Chambers of Commerce and Industry)	WABO	Wet Algemene Bepalingen Omgevingsrecht (General Environmental Law Act)

Acknowledgement:

The reports and databases completed by the HyLaw[1] and H2ME[2] projects were invaluable in completing this report

[1] HyLaw Online database: https://www.hylaw.eu/about-hylaw
[2] Hydrogen Mobility Europe: https://h2me.eu/reports/

Executive Summary

This report considerers the **variation of hydrogen (H_2) legislation and standards** that affect issues such as safety, fuelling, and validation of H_2 vehicles **across the North Sea Region (NSR). The North Sea Region includes territory from the seven nations which are connected by the North Sea. The report presents:**

- **A unified FCEV guide that is compliant across all NSR countries; and**
- **A unified H2 transport guide that is compliant across all NSR countries.**

Applicable EU, national, regional, and local legislation was reviewed and is summarised in the report. The main message that emerged was that legislative requirements for H_2 production, storage, distribution, and use increase with the amount of H_2 produced or stored, and therefore has different implications for users of H_2 vehicles, and those involved in H_2 production, transportation, and retailing from H_2 refuelling stations (HRS).

This report focuses on users of fuel cell electric vehicles (FCEVs), although legislation relevant to those involved in H_2 production, distribution and retailing was also surveyed and summarised. Findings relevant to these different stakeholders are summarised below:

FCEV users and fleet operators

FCEVs refuel with compressed H_2 gas at HRS. H_2 is stored on the vehicle in cylinders at a maximum pressure of 350 or 700bar. There is some interest in liquid hydrogen for certain applications. The HRS refuelling process is governed by internationally acknowledged standards such as SAE J2601 for 700 bar refuelling. A typical FCEV passenger car or small van consumes between 1 and 1.4 kg of H_2 per 100 km driven and stores less than 10 kg of H_2 onboard. Due to the relatively small quantity of H_2 stored on board, provided a vehicle has been type approved for use on public roads it can be driven the same way as a conventional vehicle. Some local restrictions (for example limitations on parking underground, which should be avoided whenever possible) may apply. If a vehicle has received prototype or small series approval, then additional considerations, such as a need to inform regional fire services, can also apply. The same principles apply to all vehicles, including busses, HGVs, and non-road mobile machinery.

FCEV manufacturers and converters

Vehicle manufacturers and converters need approval that their vehicles can be operated on public roads in the NSR. Approval and certification of H_2 vehicles is a nationally devolved activity. All EU countries have procedures and departments for providing approval for either small numbers of vehicles or type approval for a larger number of vehicles. The general principles covering the approval of vehicles for use on the roads in the NSR are closely related to EU legislation and directives and type-approval of a vehicle in one EU state should be valid in all EU nations. In practice, the German automotive sector has the most experience of H_2 vehicle type approval.

Stakeholders involved in H_2 production, transportation, and retailing

Although not the focus of this work, applicable legislation for H_2 production, transportation, storage, and dispensing, particularly regarding HRS, was reviewed and is summarised in the report. The main message that emerged is that as the amount of H2 involved increases, so do the regulations, codes and standards (RCS) requirements.

1 Introduction

1.1 Introduction to HyTrEc2

In 2015, at the 21st Conference of the Parties (COP) in Paris, 195 countries signed a legally binding agreement to keep global warming "well below 2°C above pre-industrial levels". Achieving this target requires fundamental changes to our use of materials and energy. No single technological advance can tackle this issue. A combination of energy efficiency, renewable and low carbon energy is required [3]. COP26 is due to take place in October of 2021 and is considered by many the last opportunity for the world to avoid a global temperature increase of greater than 1.5°C above the pre-industrial average.

The Hydrogen Transport Economy (HyTrEc) for the North Sea Region project identified constraints to the access and development of alternative fuels in rural settings. HyTrEc supported the validation, promotion, and adoption of innovative H2 technologies across the North Sea Region (NSR). HyTrEc hoped to enhance the NSR's economic competitiveness within the transport and associated energy sectors. Following on from HyTrEc, the HyTrEc2 project brings together organisations with an interest or experience in hydrogen (H_2). The HyTrEc2 consortium collaborate on the development of strategy and initiatives across the NSR. HyTrEc2 will support the further use of H_2 fuel cell electric vehicles (FCEVs) in the NSR. The HyTrEc2 project is part of the Interreg VB North Sea Region Programme, and the European Regional Development Fund.

98% of transport is still fossil fuel based. Sustainable transport solutions such as H_2 will play a key role in achieving EU energy and climate change targets. H_2 FCEVs have a longer range than an equivalent battery electric vehicle (BEV) and refuelling times comparable to existing fossil-based fuels. Extended range is essential in the NSR, which has many small and medium-sized cities. Cities with a large suburban and rural hinterland. Prolonged charge times may require commercial fleets to purchase additional vehicles. As large fleet operators cannot yet make a business case for the adoption of FCEVs, there is a need for more cost-effective H_2 production, storage, and distribution. Reduced H_2 costs and a better understanding of implementing H_2 technologies will encourage the adoption of H_2 technologies.

The key aim of HyTrEc2 is to foster a FCEV market and to develop and promote the NSR as a centre for excellence for H_2 and fuel cells. The project aims to reduce the cost of H_2, H_2-powered vehicles, and reduce CO_2 emissions by:

- Improving the operational efficiency of a wide range of vehicles such as vans, large trucks and refuse collection vehicles.
- Improving the supply chain and training so that the NSR becomes a centre of excellence for H_2 transport and helps create a competitive environment.
- Developing innovative methods for the production, storage, and distribution of green H_2.
- Ensuring that the NSR is the dominant region in the EU in terms of H_2 transport. The project will complement national programmes and facilitates joint NSR approaches and common standards.

[3] *Hydrogen Supply Chain Map for the North Sea Region March 2018*

1.2 Introduction to Cenex

Cenex was established as the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies in 2005.

Today, Cenex focuses on low emission transport & associated energy infrastructure and operates as an independent, not-for-profit research technology organisation (RTO) and consultancy, specialising in the project delivery, innovation support and market development.

We also organise Cenex-LCV, the UK's premier low carbon vehicle event, to showcase the latest technology and innovation in the industry.

Our independence ensures impartial, trustworthy advice, and, as a not-for-profit, we are driven by the outcomes that are right for you, your industry and your environment, not by the work which pays the most or favours one technology.

Finally, as trusted advisors with expert knowledge, we are the go-to source of guidance and support for public and private sector organisations along their transition to a zero-carbon future and will always provide you with the insights and solutions that reduce pollution, increase efficiency and lower costs.

To find out more about us and the work that we do, visit our website:

www.cenex.co.uk

2 Scope of Work

This report considerers the variation of H2 regulations, codes, and standards (RCS) that affect issues such as safety, fuelling and validation of H2 vehicles across the NSR. The report focuses on users of FCEVs, although legislation relevant to those involved in H2 production, distribution and retailing was also surveyed and is presented in appendices. The information presented in this report is not a substitute for reading and understanding the relevant legislation in companies' business operations. This report is intended as a guide to assist companies new to H2 technologies in getting to grips with most significant legislative requirements across the EU, and some of the variation in legislative requirements across the NSR countries.

Individual readers of this document may not need to read all sections and subsections to gain the information they require. Table 1 summarises each section of the report to assist the reader in navigating this document. It is recommended that readers of this report familiarise themselves with EU legislation and standards on in section 5 as a minimum.

Section	Description
1 Introduction	An overview of the HyTrEc2 project and consortium members.
1.2 Introduction to Cenex **Cenex was established as the UK's first Centre of Excellence for Low Carbon and Fuel Cell technologies in 2005.** **Today, Cenex focuses on low emission transport & associated energy infrastructure and operates as an independent, not-for-profit research technology organisation (RTO) and consultancy, specialising in the project delivery, innovation support and market development.** **We also organise Cenex-LCV, the UK's premier low carbon vehicle event, to showcase the latest technology and innovation in the industry.** **Our independence ensures impartial, trustworthy advice, and, as a not-for-profit, we are driven by the outcomes that are right for you, your industry and your environment, not by the work which pays the most or favours one technology.** **Finally, as trusted advisors with expert knowledge, we are the go-to source of guidance and support for public and private sector organisations along their transition to a zero-carbon future and will always provide**	Definition of the topics covered in this report

you with the insights and solutions that reduce pollution, increase efficiency and lower costs. **To find out more about us and the work that we do, visit our website:** **www.cenex.co.uk**	
Scope of Work	
3 Introduction to Hydrogen for Transport in the NSR	This section provides a brief introduction on how H2 is produced, stored, dispensed, and used to power FCEVs.
4 Energy Policy, Storage and Hydrogen Production in the NSR	A brief review of each NSR country's energy policy , H2 policy, and H2 deployment is presented. Readers are advised that each country section can be read independently.
5 EU Legislative Requirements for Operators of Hydrogen Vehicles and for Those Involved in Hydrogen Production, Transportation and Retailing	This section is a summary of applicable EU RCS for Fuel Cell Electric Vehicles in the NSR. Summarises the main directives and legislation that are important for potential manufacturers, suppliers, and users of FCEVs across the NSR.
6 NSR Regulatory Requirements	This section provides a detailed overview of H2 RCS in each NSR country that participates in HyTrEc2 with a focus on the legislative and permitting requirements that add to the legislative requirements for hydrogen transport technologies.
7 Lessons Learned	Practical experience in the set up and operations of hydrogen transport technologies has given the Hytrec2 consortium invaluable experience in the practical application of hydrogen transport technologies. This section presents a summarised list of key lessons learned.
8 Summary	A summary of the report is presented, including a mass based reference table for EU legislation relevant to hydrogen technologies. A unified NSR-RCS guidance table summarises the most stringent additional requirement (beyond the minimum EU requirements) on hydrogen transport technologies imposed across the NSR.

Table 1: Document structure summary

2.1 Disclaimer and How to Use This Document

Despite the care that was taken while preparing this document, the following disclaimer applies: The information in this document introduces H_2 transport, uptake across the NSR, and the applicable legislation and standards for H_2 transport. The following information is based on a literature review. No guarantee or warranty is given that the information is complete or accurate. The user thereof employs the information at his/her sole risk and liability. The report reflects only the authors' views.

Cenex, the HyTrEc2 consortium, The North Sea Region Programme Secretariat and the European Union are not liable for any use that may be made of the information contained herein.

This document is based on an assessment of EU and NSR legislation and standards relating to H_2 transport. In addition to original legislation , directives and related official guidance documents, this report also draws on the HyLaw project database and project reports, H2ME project reports and the NSR local authority regulatory databases. Partners with direct experience of the operation of H_2 vehicles in NSR countries have also been consulted and provided guidance. All information provided is correct as of May 2019. Some data has been updated since that time and is referenced accordingly. Any individual or organisation using this document to inform their decision making on the topic of H_2 technologies must review the relevant legislation and ensure no amendments or new legislation has come into force in the time since this document was written.

3 Introduction to Hydrogen for Transport in the NSR

H_2 has a long history as an industrial gas with practical applications from the industrial revolution onwards. H_2 has been used as a coolant in static power generation for industrial processes since the 1930's. The dependence of many industries on H_2 has created a great deal of expertise in how to produce, store, dispense and use H_2 in a wide range of commercial and industrial activities. However, H_2 for transport and energy storage (outside of industrial chemical plants) is an emerging technology.

3.1 Hydrogen Basics

Hydrogen (H_2) is a colourless, odourless gas that is lighter than air, that burns with a flame that is difficult to see in daylight.

H_2 is very much lighter than air and diffuses easily. Thus, unlike heavier gaseous fuels, if a H_2 leak occurs in an open or well-ventilated area, its diffusivity and buoyancy will help to reduce the likelihood of a flammable mixture forming in the vicinity of the leak. Intelligent equipment design and layout, based on H_2's buoyancy and dispersion rate, can improve the safety of sites involving H_2 [4].

All materials have maximum and minimum ratio of mixtures with air (and the oxygen found in air) in which they will burn. Theses minima and maxima are known as either flammability or detonation limits. Typically, the safety of H_2 and other flammable gasses are discussed in terms of their lower and upper Combustion or flammability limits. When mixed with air in a ratio between 4% and 75% H2, H2 will ignite very easily. Any combustible gas requires controls of ignition sources, but this is especially true for H_2. H_2 has a typical lower flammability limit (LFL) of 4% compared to most other combustion gases (propane LFL = 2.1%, Methane LFL = 5%). However, it has a much higher upper flammability limit (UFL) of 75% when compared to other gases (propane UFL = 9.5%, Methane UFL = 15%).

Any H_2 installations must be designed to take advantage of H_2's rapid acceleration upwards to allow escape, with dedicated H_2 detectors at key locations. **Once a leak is detected, automated systems must eliminate all ignition sources, including static discharge**.

3.2 Hydrogen Production

H_2 is not a fuel in the traditional sense, as it rarely exists in a raw state that can be mined directly and, with minimal refining, used as an energy source. Instead, it is an *energy vector*, because it is produced from other fuels and allows their energy to be carried and then converted to other forms of energy.

Production of H_2 from fossil sources currently accounts for 95% of global H_2 production[5]. H_2 production techniques include:

- Steam methane reforming (SMR) is the most widely used fossil H_2 production technique. SMR is the reaction of natural gas with water at high temperatures, in the presence of a catalyst, to produce H_2 and carbon dioxide.
- Electrolysis uses a direct electric current to drive a chemical reaction. If water is electrolysed, water breaks down into H_2 and oxygen. Electrolysis of water and aqueous solutions of water with other chemicals accounts for the remaining 5% of H_2 production.

H_2 produced from fossil sources is called grey H_2. Grey H_2 manufacture is a well-established and highly efficient industrial process, but it is very energy intensive and involves significant carbon

[4] Installation permitting guidance for hydrogen and fuel cell stationary applications: UK version Prepared by Health and Safety Laboratory for the Health and Safety Executive 2009: http://www.hse.gov.uk/research/rrpdf/rr715.pdf

[5] Shell Hydrogen Study, 2017: https://hydrogeneurope.eu/sites/default/files/shell-h2-study-new.pdf

emissions. A future transition to zero-emission mobility will require considerable amounts of cleaner, zero-emission H_2. Options for clean H_2 production include:

- *Blue Hydrogen*, manufactured from traditional processes but incorporating carbon capture, storage, and use (CCSU).
- *Green Hydrogen* produced from renewable sources. Examples include electrolysis of water powered by renewable electricity.

3.3 Hydrogen Storage

H_2 is stored on FCEVs in cylinders as a **compressed gas**. Conventional gas cylinders and tankers are held at a pressure of 200 bar (one bar is approximately equivalent to atmospheric pressure). The pressure may be increased, which in turn increases energy storage density. Most commercially available passage car FCEVs store between 5 kg and 6 kg of H_2 onboard in cylinders at 700 bar; commercial vehicles and buses often store 20 kg and 35 kg H_2 at 350 bar in cylinders.

- H_2 can also be stored and transported as a **cryogenic liquid**, held at a temperature below -250˚C. Although liquid H2 is more energy dense than compressed H_2 gas and would therefore offer longer range to road going vehicles, it is usually not in use in road vehicle applications and will not be discussed further here. A detailed assessment of the legislation, codes and standards for liquid hydrogen was carried out in the PRESHLY and HySAFE projects[6]

- **Metal hydrides** are used as a H_2 storage medium. Hydride storage is often based on sodium aluminium hydrides or similar materials. These materials are flammable solids and can react violently with water to produce H_2 and a corrosive aqueous solution. Hydride storage systems can be suitably designed to avoid these hazards. Due to their weight, hydride storage systems are uncommon in road transport. However, their increased weight may be advantageous in some applications such as rail, maritime or certain materials handling operations.

- **Organic and inorganic liquid carriers** are active topics of research for H_2 storage and transport. Liquid H_2 carriers such as formic acid, ammonia, and cycloalkanes (for example Toluene) are all possible liquid H_2 carriers.

3.4 Hydrogen Refuelling Stations (HRS)

H_2 can be dispensed to vehicles through pressurised gas delivery. Filling an FCEV with H_2 is a broadly similar experience to filling a conventional internal combustion engine (ICE) vehicle with diesel or petrol.

3.4.1 Hydrogen Refuelling Systems

700 bar H_2 requires the HRS to have a small amount of H_2 pressurised to 800 or 900 bar to ensure rapid fill speeds. Despite the vast knowledge on H_2 best practice in an industrial setting, encouraging H_2 as a fuel for public use has been problematic. For many HRS projects completed in the past, local civil authority planning legislation and standards have hindered the uptake of H_2 as a mass-market transport fuel. For example, HRS planning and commissioning can take two or more years to complete in the UK.

A typical HRS set up is shown below in Figure 1[7]. In the refuelling process low-pressure H_2 (generated on-site or transported in) is compressed to a higher pressure (typically ~ 900 bar) and cooled (to -40° if the station complies to the SAE J2601 standard[8]) before being dispensed to the vehicle.

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[6] PRESHLY D2.1: Regulations, Codes and Standards (RCS) Analysis https://www.hysafe.info/wp-content/uploads/sites/3/2018/09/HySafe_RCS-Report_D2.1_tj_final.pdf
[7] https://hydrogeneurope.eu/refueling-stations
[8] Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles: https://www.sae.org/standards/content/j2601_201003/

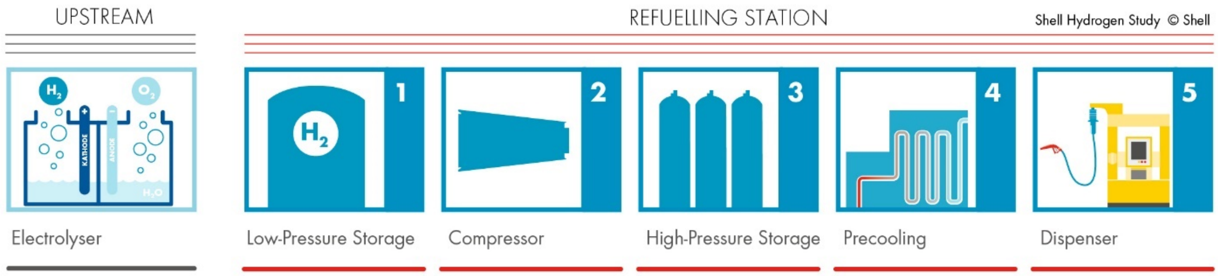

Figure 1. Schematic of a typical hydrogen refuelling station

There are currently two main technical issues encountered with HRS:

- **Cooling**: H_2 is a relatively unusual gas because it has a 'reverse Joule -Thompson effect'; i.e., unlike common aerosol gases, it heats up when it expands. The increase in temperature makes the rapid refuelling of vehicles problematic. The refueller must include cooling facilities; specifically, H_2 must be precooled to -40° prior to dispensing if the station complies to the SAE J2601 standard[9]. If the cooling system is not sized and controlled appropriately; the number of vehicles that can be fuelled at a given pump will reduce. The cooling unit becomes the limiting factor on how many vehicles can be fuelled in rapid succession[10].
- **Compression**: compressors have typically been found to be the main source of failure in HRS.[11] As high pressure H_2 compressors are being produced in larger numbers, and novel compression techniques refined, compressor failure rates are expected to improve. Additionally compressor costs have traditionally been the highest capital and expenditure for new HRS[12]

There were 177 HRS in Europe in February 2020, of which 87 are in Germany[13]. Delays in the deployment of HRSs in some NSR countries have been due to the lack of relevant knowledge and experience in local authorities that grant planning permission to stations. European projects such as HyFive, HySafe, HyTrEc, CHIC, BIGHIT, H2ME, and HyLaw (and many others) have all contributed to the knowledge and experience base of HRS installations in the NSR.

Increasing efforts are being made in NSR countries to improve the knowledge base available to local and regional authorities. For example, in the UK the 'Bluebook'[14], combined with Energy Institute guidance documents[15], give local planning authorities rigorous processes and procedures to adhere to. The Bluebook and Energy-Institute guidance provide local authority officers with a checklist, to assist with 'under the canopy' installations of HRS installed at traditional fuelling stations.

3.5 Hydrogen Vehicles

H_2 can be reacted in internal combustion engines, either as a standalone gas or, more commonly, in combination with other fuels. At the time of writing, so-called dual-fuel and co-combustion uses of H_2 are being investigated by a minority of H_2 for transport stakeholders.

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9 Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles: https://www.sae.org/standards/content/j2601_201003/
10 http://fsec.ucf.edu/en/publications/pdf/fsec-cr-1986-14.pdf
11 Hydrogen Mobility Europe (H2ME): Vehicle and Hydrogen Refuelling Station Deployment Results, 2017: https://www.mdpi.com/2032-6653/9/1/2/htm
12 Hydrogen Station Compression, Storage, and Dispensing Technical Status and Costs, 2014: https://www.nrel.gov/docs/fy14osti/58564.pdf
13 https://www.h2stations.org/press-release-2020-02-19/
14 Design, construction, modification, maintenance and decommissioning of filling stations (4th edition)
15 Guidance on hydrogen delivery systems for refuelling of motor vehicles

The focus of H_2 in road transport, and of this report, is on FCEVs. In an FCEV, H_2 and oxygen are combined electrochemically in a fuel cell to produce electricity, heat and water as shown in Figure 2[16].

Step 1 Hydrogen stored in the tank is supplied to the fuel cell stack

Step 2 An inflow of air is supplied to the fuel cell stack

Step 3 The reaction of oxygen in the air and hydrogen in the fuel cell stack generates electricity and water

Step 4 Generated electricity is supplied to the electric motor

Step 5 Water is emitted

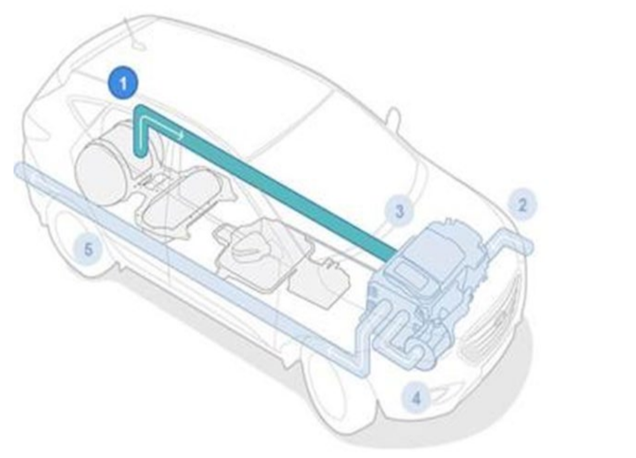

Figure 2. Fuel cell electric vehicle

A typical passenger car FCEV consumes between 1 and 1.4kg of H_2 per 100 km driven and stores less than 10 kg of H_2 onboard. Due to the relatively small quantity of H_2 stored on board, provided a vehicle has been type approved for use on public roads (see below) it can be driven the same way as a conventional vehicle, although some local restrictions (e.g., limitations on parking underground) may apply. Hydrogen buses are available and store in the region of 22 kg of hydrogen on board. Demonstrations projects for large heavy goods trucks are taking place (notably in Switzerland at the time of writing) and on-board hydrogen storage is in the order of 30 kg or higher. Legislation applicable to H_2 vehicles are discussed further in the next sections.

3.6 Hydrogen Policy development in the NSR

Across Europe, renewable energy generation has helped to decarbonise power generation. A mismatch in the time when renewable electricity is produced, and the time when electricity is required, may result in the overproduction of electricity. Renewable energy generation is often switched off at such times. This disconnect of renewable energy generation from the grid is called a ‘constraint-event’ or ‘curtailment’. As renewable energy generation is added to the networks, the number and duration of constraint-events increases. H_2 generated through renewably powered electrolysis has the potential to store renewable energy over long periods. Electrolysis uses electrical energy to split apart water molecules to produce H_2 and oxygen. The source of electricity is important. There is limited evidence of an environmental benefit in generating H_2 from an electrolyser powered by electricity from fossil fuels.

When there is an instantaneous demand for renewably generated electricity, it is most efficient to use the available power immediately. Any energy storage system will have losses and inefficiencies. However, if the network is constrained, electrolysed H_2 provides significant added benefit to renewable generation. The EU uses 25,000 TWh per year of energy in all sectors[17]. To meet the EU’s legal obligation to store 100 days of energy, this requires 6,850 TWh of storage. Compressed H_2 is, arguably, the most cost-effective zero-carbon solution for storing 6,850 TWh of energy. When there is ample renewable energy, but insufficient demand or export infrastructure, electrolysers can

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[16] Hydrogen Mobility Europe (H2ME): Emerging Conclusions, 2018:https://h2me.eu/wp-content/uploads/2018/11/H2ME_Emerging-Conclusions-_introduction-H2-mobility.pdf.

[17] https://ec.europa.eu/eurostat/cache/sankey/sankey.html?geos=EU28&year=2017&unit=GWh&fuels=TOTAL&highlight=_&nodeDisagg=0101000000000&flowDisagg=false&translateX=39.168278970149956&translateY=75.85322360716424&scale=0.7578582832551992&language=EN

use excess power to create H_2. H_2 can then be stored or exported as required. H_2 offers the hope of using large scale renewable energy when it would otherwise be wasted. Renewable H_2 also offers the possibility of opening markets, other than electricity generation, to renewable energy generation companies. Electrolytic production of H_2 from renewables is often termed 'power-to-gas' (P2G). As renewably powered electrolysis becomes common, there is hope that price reduction for renewably generated H_2 will enable the decarbonisation of fossil H_2 feedstocks for industrial processes and heating.

In the UK and much of Northern Europe, many homes are connected to a natural gas (methane) grid. Fuel is provided directly into a home boiler. The feasibility of utilising this existing infrastructure to deliver H_2 alongside natural gas is generally accepted. In the UK and Germany, up to 20% (by volume) of domestic natural gas could be replaced by renewable H_2. 20% H_2 in the national gas grid would require minimal changes to existing infrastructure[18]. Combined with air source heat pumps and other electric heating systems, there is a strong possibility that renewables could displace natural gas heating (domestic and commercial). Industrial heating and processing can be more challenging in some sectors and may have to rely on biomethane mixtures or similar renewable fuels to achieve long term zero-emission targets.

Hydrogen is expected to become an important energy vector for transport, heat, and power across the NSR, as well as continuing in its traditional role as a critical chemical feedstock.

The transition to renewably generated H_2 has traditionally relied on fossil-fuel-based H_2 in earlier research projects. Carbon capture storage and use (CCSU) may enable the continued use of fossil-based feedstocks and processes (such as SMR) without significant increases to greenhouse gases (GHGs).

To comply with international and national global warming commitments, decarbonisation by utilising zero-emission H_2 must begin with technologies that are available today. The latest generation of proton exchange membrane/polymer electrolyte membrane (PEM) electrolysers have improved efficiencies, improved response times and can take advantage of constrained renewables. H_2 fuel cell vehicles are entering the market. High energy density requirements like shipping and air transport are also being considered. H_2 fuelled combined heat and power (CHP) can supply low-grade heat and electricity to industry. Chemical feedstocks such as ammonia and methanol production may also be decarbonised with the use of H_2 from renewables rather than reformed fossil fuels. Wide-scale decarbonisation of such a significant portion of the NSR economy requires rapid expansion of renewable energy generation across the NSR.

[18] https://www.theccc.org.uk/wp-content/uploads/2019/05/Net-Zero-The-UKs-contribution-to-stopping-global-warming.pdf

4 Energy Policy, Storage and Hydrogen Production in the NSR

All NSR countries have similar commitments to reduce emissions from transport, heat, and power generation. Each presents different strategic and policy drivers to ensure that change happens, depending on the country's specific circumstances. A brief review of each NSR countries energy policy[19], H_2 policy, and H_2 deployment is presented.

4.1 Belgium

Energy policy is divided between the federal and regional governments. Belgium's extensive gas transport infrastructure, and gas market is well-integrated with neighbouring countries. Emergency oil stocks are high. Nuclear powered electricity generation provides approximately 50% of Belgium's electricity production. Renewable energy accounts for 9% of Belgium energy at the time of writing[20] The current policy is to close all nuclear power plants between 2022 and 2025. To make up for lost nuclear power generation, the Belgium government plans to increase natural gas and renewables generation. In addition, enhanced interconnections with neighbouring countries are also planned.

4.1.1 Key Policy and Energy Goals

Three major transnational European networks for transport (TEN-T) corridors cross Belgium:

- North Sea-Baltic corridor
- Rhine-Alpine corridor and
- North Sea-Mediterranean corridor.

The Belgium road and refuelling network is critical in the development of H_2 refuelling infrastructure for freight and logistics for the European Union. The federal state of Belgium is comprised of communities (Flemish/Dutch-speaking, French-speaking, and a small German-speaking community) and regions (Flanders, Wallonia, Brussels). This mix of communities leads to six regional authorities. Integration of H_2 policy across them can be problematic. Public procurement policies for H_2 vehicles with zero-emission targets are in place at national, regional and community levels. The H_2 in mobility agenda is included in national and regional policies.

The Belgian national energy and climate plan proposes renewables target of 18.3% by 2030[20] . There is no specific target for H_2 in the plan.

4.1.2 Key Hydrogen Policy Papers

The H_2 infrastructure for transport-2-Corridors project (HIT-2) has published a white paper which proposes a national H_2 refuelling infrastructure plan for Belgium[21]. This document includes proposals for federal, regional, provincial, and local policies to facilitate the H_2 transport economy in Belgium.

4.1.3 Current Status of Hydrogen Deployment (Number of HRS and Vehicles)

The port of Antwerp is home to some of the largest H_2 production facilities in Europe, and the world's most extensive network of H_2 pipelines. The Hydroville is the world's first accredited small passenger vessel powered by H_2 in a diesel engine.

- 5 H_2 buses.
- 11 forklifts.
- 3 HRS.[22]
- 4 cars.

[19] https://www.iea.org/regions/europe
[20] https://windeurope.org/newsroom/news/belgium-energy-and-climate-plan-proposes-renewable-energy-target-of-18-3-by-2030/#:~:text=There%20is%20now%20an%20EU,9.1%25%20of%20Belgium's%20energy%20demand.
[21] https://www.waterstofnet.eu/_asset/_public/H2MobilityBelgium-WaterstofNet-Final.pdf
[22] https://www.h2stations.org/

4.2 Denmark

Denmark is internationally recognised as a global leader in integrating renewable energy into a secure reliable power grid. Denmark currently has the highest share of wind in total primary energy consumption of any IEA country. Most Danish power generation comes from wind and bioenergy. The large-scale use of combined heat and power (CHP) plants, heat storage, and wind power promotes the integration of heat and electricity systems. As in all countries, more needs to be done to limit emissions from transport.

Denmark has a wide range of policy to encourage renewable energy in a variety of sectors[23]. Renewable energy sources are promoted through a premium tariff and net-metering. A separate fund supports pilot project windmill construction. Renewable heating projects are tax exempt for the production, supply and use of energy. The use of biogas for heating purposes is supported through a direct tariff. The main incentive for renewable energy use in transport is a quota system. Selling of biogas for transport purposes is supported through a direct tariff. Renewable energy has priority access to grid networks.

Bicycle and public transport is expected to account for 75% of all journeys in Denmark by 2025[24]. Danish Partnership for H_2 and Fuel Cells (DPHFCs) is an organisation that brings together Danish manufacturers, research institutions, network organisations and public authorities under the common goal of promoting H_2 and fuel cells in Denmark. The members deal with all aspects of H_2 and fuel cells. The DPHFCs actively develop H_2 technologies to create a competitive alternative energy market.

4.2.1 Key Policy and Energy Goals

Denmark aims to achieve 55% of power generation through renewable energy by 2030[25]. Energinet has conducted a system report for Danish energy solutions in 2035. The recommendations and projections anticipate significant production of H_2 via electrolysis [26].

4.2.2 Key Hydrogen Policy Papers

FCEVs are exempt from vehicle taxation until 2022[27]. The Danish national integrated energy and climate plan[28] specifically mention H_2 as a transport fuel, as a large-scale energy store, and outlines the importance of H_2 to facilitate sector coupling. 128 million DKK have been ringfenced for two Power-to-X-projects. Both projects include large scale production and storage of H_2 under “near market” conditions.

4.2.3 Current Status of Hydrogen Deployment (# of HRS and Vehicles)

Denmark boasts the world’s first fully connected national HRS network[29, 30]. Ten HRS provide green H_2 at strategic sites across the country. 50% of the population live within 15 km of a working HRS, and all HRS supply 100% renewably generated H_2. Standard FCEV passenger cars can navigate to all locations in Denmark using the publicly available HRS network.

- Ten HRS.[22]
- 83 FCEV vehicles were reported as operating in Denmark in 20XX[31].
- The first three FCEV buses were delivered in early 2020[32].

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[23] http://www.res-legal.eu/search-by-country/denmark/
[24] https://investors-corner.bnpparibas-am.com/investing/energy-policy-denmark/
[25] necp_factsheet_dk_final.pdf (europa.eu)
[26] https://energinet.dk/Analyse-og-Forskning/Analyser/RS-Analyse-Marts-2018-Systemperspektiv-2035
[27] https://h2me.eu/2019/01/03/prolonged-tax-exemption-for-fcevs-in-denmark/
[28] https://kefm.dk/media/12980/denmarks-national-energy-and-climate-plan.pdf
[29] https://www.energy.gov/sites/prod/files/2018/10/f56/fcto-infrastructure-workshop-2018-5-frihammer.pdf
[30] https://www.lestudium-ias.com/sites/default/files/public/nielsen_-_a_hydrogen_adventure_in_denmark.pdf
[31] https://www.hylaw.eu/sites/default/files/2018-10/National%20Policy%20Paper%20-%20Denmark%20%28EN%29.pdf
[32] https://www.electrive.com/2020/03/25/first-fuel-cell-buses-hit-the-roads-in-denmark/

4.3 Germany

The energy transformation (Energiewende) is Germany's plan to achieve a low carbon nuclear free economy[33]. Plans to phase out nuclear power are well on track. Reduction in coal use has been harder to achieve. Germany's response to the COVID 19 pandemic includes a seven-billion-euro support package for H_2 research and deployment projects[34].

Germany has the stated ambition to be the first country in the world with a fully operational H_2 refuelling infrastructure (an ambition the Danish network has arguably already achieved.) German H_2 production policy is focused on the development of H_2 production from renewables. Germany is pioneering the development of power-to-gas (P2G). P2G is the production of H_2 from renewables. Renewable H_2 is added to the gas grid. The German Government, along with the science and industry sectors, supports the development of fuel cell and H_2 technologies in Germany in the form of a strategic alliance known as the national H_2 and fuel cell technology innovation programme (NIP).

4.3.1 Key Policy and Energy Goals

The Federal Government plans to reduce greenhouse gas emissions globally. Developing a German H_2 market will promote H_2 as a decarbonisation option not just for Germany but for her trading partners as well. This is a key contribution to global climate change mitigation. In terms of transport, the German government is dedicated to enhancing transportation and distribution infrastructure to ensure the use of H2. This includes building and expanding a dedicated H_2 network.

4.3.2 Key H2 Policy Papers

Released in June 2020, the Federal German government national H_2 strategy is the principle document to guide H_2 policy development in Germany [35]. The strategy is supported by a wide variety of existing policies and funding programmes, as well as committing the German government to future policy development and spending.

4.3.3 Current Status of H2 Deployment (# of HRS and Vehicles)

- 10MW electrolyser (refinery based)[36]
- 84 H_2 stations are operational in Germany[37].
- 386 H_2 cars[38].
- 70 fuel cell forklifts[39].
- 12 H_2 busses[40].
- Two H_2 trains[41].

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[33] https://www.cleanenergywire.org/germanys-energiewende-brief
[34] https://www.businessgreen.com/news/4016109/green-recovery-germany-unveils-plans-eur40bn-climate-spending-surge
[35] https://www.bmbf.de/files/bmwi_Nationale%20Wasserstoffstrategie_Eng_s01.pdf
[36] https://www.shell.com/energy-and-innovation/new-energies/hydrogen.html
[37] https://h2.live/en
[38] https://www.cleanenergywire.org/news/little-demand-fuel-cell-cars-germany#:~:text=A%20mere%20386%20hydrogen%20fuel,stations%20and%20the%20high%20price.
[39] https://www.h2-international.com/2019/11/17/new-call-for-fc-forklifts/

[40] https://www.fuelcellbuses.eu/category/demos-europe
[41] https://www.theguardian.com/environment/2018/sep/17/germany-launches-worlds-first-hydrogen-powered-train

4.4 Netherlands

The Netherlands government has presented a long-term energy plan, stipulating no new cars with combustion engines may be sold from 2035 onwards. Also, the government has indicated that by 2050 domestic heating will no longer be fuelled by natural gas. This is a significant step for a nation that is Europe's second largest producer of natural gas[42].

4.4.1 Key Policy and Energy Goals

The Energy Agenda[43] outlines the Dutch government's policy and goals to not only achieve NetZero by 2050, but to proactively lead the Netherlands and the rest of Europe in decarbonising national energy policy. The Dutch government assessment is that economic damage is limited by making changes over the longest period possible. To that end The Netherlands has decided to proactively implement low and zero emission solutions wherever they are viable.

The recently published government strategy on H_2[44] states that low carbon H_2 is a crucial link in the energy transition. The Dutch government is preparing to transition the natural gas pipeline hub in The Netherlands to a H_2 pipeline hub. Port and industry clusters of H_2 use are a key part of this strategy

4.4.2 Key Hydrogen Policy Papers

National Climate Agreement[45] has provisions for 50 refuelling stations, 15,000 fuel cell vehicles and 3,000 heavy-duty vehicles by 2025, with 300,000 fuel cell vehicles by 2030. The major ports of the country have stated they are willing to participate in the roll out of critical infrastructure to facilitate this wider adoption of H_2 transport[44].

4.4.3 Current Status of H2 Deployment (# of HRS and Vehicles)

- 1MW hydrogen electrolyser[46]
- Four H_2 stations.[22]
- 36 H_2 cars.
- Ten H_2 busses.
- Four H_2 powered refuse collection vehicles.

4.5 Norway

With the significant potential of renewables and the importance of natural gas production, Norway sees H_2 as an important part of the future energy transition. Norway has had a high uptake of BEVs. Norway's geography and population density make the development of H_2 infrastructure a challenge. HRS are currently focused on Oslo. Marine transport is a major area of interest given Norway's shipping heritage as is the production of H_2 from natural gas. Norway has recently updated its climate emissions targets and now anticipates renewables will reduce all emissions by 55% compared to 1990 levels[47] of all energy requirements by 2030

[42] https://www.iea.org/reports/energy-policies-of-iea-countries-the-netherlands-2014-review
[43] https://www.government.nl/documents/reports/2017/03/01/energy-agenda-towards-a-low-carbon-energy-supply
[44] https://www.government.nl/binaries/government/documents/publications/2020/04/06/government-strategy-on-hydrogen/Hydrogen-Strategy-TheNetherlands.pdf
[45] https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/national-climate-agreement-the-netherlands
[46] https://www.itm-power.com/news/opening-of-the-gasunie-1mw-green-hydrogen-electrolyser-plant-in-the-netherlands
[47] https://www.regjeringen.no/en/aktuelt/norge-forsterker-klimamalet-for-2030-til-minst-50-prosent-og-opp-mot-55-prosent/id2689679/

4.5.1 Key Policy and Energy Goals

The four key energy policies and goals for the Norwegian energy sector are[48] :

- Improving security of supply.
- Profitable development of renewable energy.
- More efficient and climate-friendly energy use.
- Value creation based on Norway's renewable energy resources.

4.5.2 Key Hydrogen Policy Papers

The White Paper on Norway's energy policy: Power for Change is the key document driving Norwegian energy policy[49]. In addition, a national H_2 strategy was recently announced[50]. The document contains an enforced and significant commitment to H_2 adoption. Pilot and demonstration projects are a key element in executing this policy. Industry and transport, with high-speed passenger ferries highlighted as adopters of H_2 technology.

4.5.3 Current Status of H2 Deployment (Number of HRS and Vehicles)

- Three H_2 stations[51].
- 160 H_2 cars.
- Two H_2 heavy goods vehicles.

4.6 Sweden

Sweden aligns with the broader EU policies on climate change mitigation and aims to achieve net-zero emissions by 2045. Sweden has the lowest share of fossil fuels in its primary energy supply among all IEA member countries, and the second-lowest carbon-intensive economy[52]. The reduction in carbon intensity has been achieved despite Sweden having a relatively high per capita energy use. In 2018 the average renewables contribution to primary electricity generation was 54%[53]. Notably CO2 taxation, energy efficiency and renewable energy policies have driven this change. Transport emissions are prioritised in the Swedish energy agenda, with a target of a 70% reduction in CO2 emissions by 2030.

4.6.1 Key Policy and Energy Goals

No official policy on H_2 has yet been published by the Swedish government. Vatgas Sweden is a public-private partnership which provides leadership in H_2 research and policy development.

4.6.2 Key Hydrogen Policy Papers

No key H_2 policy papers were identified for Sweden

4.6.3 Current Status of H2 Deployment (# of HRS and Vehicles)

- Five H_2 stations[54] (less than 50% coverage of the population).
- 29 H_2 cars.
- Two H_2 busses are due to be commissioned in 2021.

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48 https://energifaktanorge.no/en/om-energisektoren/verdt-a-vite-om-norsk-energipolitikk/
49 https://www.regjeringen.no/en/aktuelt/white-paper-on-norways-energy-policy-power-for-change/id2484248/#:~:text=Today%2C%20the%20Norwegian%20government%20presented,and%20climate%20friendly%20energy%20supply.
50 https://www.regjeringen.no/contentassets/8ffd54808d7e42e8bce81340b13b6b7d/regjeringens-hydrogenstrategi.pdf
51 https://www.thedrive.com/tech/28489/a-hydrogen-station-in-norway-blows-up-truth-is-among-the-victims
52 https://www.iea.org/news/sweden-is-a-leader-in-the-energy-transition-according-to-latest-iea-country-review
53 https://sweden.se/nature/energy-use-in-sweden/
54 http://www.vatgas.se/tanka/

4.7 United Kingdom

The UK government has a clear policy to reduce emissions to net zero by 2050. Significant reductions in the use of coal have helped to improve emissions from the UK power generation in recent years, with total greenhouse gas emissions reduced by 57% compared to 1990 levels[55]. The UK government has recognised the potential of H_2 as a low carbon energy vector. In the UK's "Clean Growth Strategy" H_2 plays a key role in enabling decarbonisation of heat and industrial processes. The UK has an urgent need to make important strategic decisions on the future of existing infrastructure and the adoption of net-zero emissions technologies. The UK H2Mobility[56] consortium was set up in 2013, as an industry led forum which facilitates regular dialog with UK Government and other public sector stakeholders, about the future strategic direction for H_2 mobility in the UK.

4.7.1 Key Policy and Energy Goals

The UK's draft integrated national energy and climate plan was published in January 2019 and predates the UK's commitment to NetZero in June 2019. An updated integrated national energy and climate plan is anticipated in 2020 and this section will be updated after the publication of the new climate plan. As part of the sixth carbon budget, the UK government to set in law a target of a 78% reduction in CO_2e by 2035. The North Sea Transition Deal seeks cross sector investment of £14-16 billion by 2030 in new technologies, including CCUS and hydrogen at scale. As hosts of the 26th COP meeting, significant announcements are in the hydrogen sector are anticipated soon. The Transport decarbonisation plan[57] was published in July 2021. The plan includes the ban on the sale of new of diesel and petrol cars by 2030, small vans and trucks (up to 26 t) from 2035, and larger trucks from 2040, or sooner.

4.7.2 Key Hydrogen Policy Papers

In 2018 the Committee on Climate Change issued the H_2 in a Low Carbon Economy report [58]. This report has been a keystone in developing the UK H_2 policy, and it is anticipated this will continue.

The Net Zero in the UK report is an updated and binding policy document since the net zero commitment of 2019 [59].

The Accelerate H_2 report from UK H2Mobility [60] presents a plan of work to accelerate H_2 deployment in the UK between 2020 and 2025.

The UK Continental Shelf Energy Integration report[61] was published in August 2020 and its findings are likely to impact the revised national energy and climate plan when it is eventually published

The UK published it's national hydrogen strategy in 2021. This is largely a time table of consultation events to develop a hydrogen strategy, funding mechanisms, standards, and policies in specific sectors. The strategy favours a twin track approach of both 'blue' and 'green' hydrogen. One of the key consultations will culminate in the release of the Hydrogen Sector Development Action Plan: a consultation event to develop a H_2 strategy for the UK oil and gas sector.

4.7.3 Current Status of H2 Deployment (# of HRS and Vehicles)

- 8 H_2 stations.[22]
- 42 H_2 cars (TBC).
- 3 refuse collection vehicles (TBC).

55 https://www.instituteforgovernment.org.uk/explainers/net-zero-target
56 http://www.ukh2mobility.co.uk/about/
57 https://www.gov.uk/government/publications/transport-decarbonisation-plan
58 https://www.theccc.org.uk/publication/hydrogen-in-a-low-carbon-economy/
59 https://commonslibrary.parliament.uk/research-briefings/cbp-8590/
60 http://www.ukh2mobility.co.uk/news-media/
61 https://www.ogauthority.co.uk/media/6625/ukcs_energy_integration_phase-ii_report_website-version-final.pdf

- 22 H_2 busses (based on 2019 data). It should be noted that the next generation of hydrogen buses are beginning to replace earlier models. The exact number on the roads is uncertain.

4.8 Key Policy and Energy Goals

The NSR has no formally established leadership. The North Sea Commission (NSC) is a members representative group and their existing strategy plan ends in 2020[62]. The NSC's primary role is to improve the coordination of funding sources, to improve cooperation between NSR countries and to promote the strength and competitiveness of the NSR both in the EU and world wide. Within that remit the NSC identifies four key strategic goals:

- "[T]*apping into 'blue' resources*,"[62].
- Promote environmentally friendly and efficient transport.
- Address energy and climate issues.
- Promoting local [NSR] partnerships.

The NSR-programme supports transnational regional development projects connecting regions from seven countries around the North Sea. It is part of the European Territorial Cooperation Objective under the European Regional Development Fund (ERDF) initiated by the EU and the European Commission.[1] The aim of the North Sea Region Programme is to 'make the North Sea Region a better place to live, work and invest in'.

4.8.1 Key Hydrogen Policy Papers

There is no specific H_2 policy for the NSC. One of the key 'axes' of the NSR-program strategy is to promote and accelerate greening of the North Sea Region economy[63].

4.8.2 Current Status of H2 Deployment (Number of HRS and Vehicles)

Taken together the NSR hydrogen transport infrastructure is summarised in Table 2

	Belgium	Denmark	Germany	Netherlands	Norway	Sweden	UK	NSR Total
Electrolysers			10MW	1MW				**11MW**
busses	5	3	12	10			22	**52**
forklifts	11		70					**81**
HRS	3	10	84	4	3	5	8	**117**
cars	4	83	386	36	160	29	42	**740**
trains			2					**2**
RCVs				4			3	**7**
HGVs					2			**2**

Table 2: Hydrogen transport technology deployment in the NSR

[62] https://cpmr-northsea.org/download/north-sea-region-2020-strategy/?wpdmdl=820&ind=1481027135786
[63] https://northsearegion.eu/media/1347/programme_2014tc16rftn005_1_2_en_web.pdf

5 EU Legislative Requirements for Operators of Hydrogen Vehicles and for Those Involved in Hydrogen Production, Transportation and Retailing

5.1 Introduction and Scope

Recent reports on EU legislative requirements for H_2 transport from the H2ME1, H2ME2, HyLaw and other projects have been completed. The HRS safety, legislation, codes, and standards report (November 2018) report[64] from H2ME. The national policy papers[65], and EU legislation and directives which impact the deployment of FCH technologies[66] from HyLaw have been of significant help in completing this report. These have looked at European legislation and identified some of the additional local legislative requirements of many of the NSR countries. This report builds upon existing research and seeks to further develop the knowledge base on standards and legislation on the production, storage and use of H_2 for transport applications. Additional information has been gained through publicly available local authority information, and through the direct experience of HyTrEc2 consortium members.

The following sections highlight legislation and standards that have been identified as potentially relating to the implementation of H_2 generation, storage, transportation, dispensing or use. The caveats outlined previously still apply, and the following list should not be considered exhaustive. All identified legislation, directives, standards, and guidelines may have been amended or modified since the time of writing (May 2019 onwards). An update of the final document will be completed prior to publication.

When developing H_2 projects and programmes, several key EU wide legislation, directives, and standards should be considered. The first step in this process is to quantify the largest likely amount of H_2 stored or generated in the life of the project. The next consideration is the likely storage pressure of the H2. Lastly, the sites and locations where the H_2 will be present (either as static storage or during its transport between sites) must be identified. The project manager can then review the legislative framework and quickly identify which, if any, of the following legislation may apply. **Many of the legislation and standards identified in this report will not apply to smaller H_2 projects, particularly fleets that are users of small numbers of H_2 vehicles rather than producers of H_2**. As a very broad generalisation, **for H_2 projects based in industrial or commercial zones, the legislative requirements become more stringent when:**

- **200 kg (or more) per day H_2 production & transport is required; or**
- **1,000 kg (or more) of H_2 storage is required**.

This report focuses on users of H_2 vehicles, particularly FCEVs, so these legislations and directives are discussed first. As stated in the previous section, these vehicles carry relatively small amounts of H2 on board; typically ~ 5 kg for FCEVs, 20 kg for bus[67], and around 30 kg or more for a fuel cell truck. As discussed below, due to the relatively small quantity of H_2 stored on board, provided a vehicle has been type approved for use on public roads it can be driven the same way as a conventional vehicle, although some local restrictions (e.g., avoid parking underground) may apply.

64 https://h2me.eu/reports/hrs-safety-regulations-codes-and-standards -report-november-2018/
65 https://www.hylaw.eu/info-centre
66 https://www.hylaw.eu/sites/default/files/2019-02/D4.4%20-%20EU%20regulations%20and%20directives%20which%20impact%20the%20deployment%20of%20FCH%20technologies_0.pdf
67 https://www.hydrogeneurope.eu/hydrogen-buses

If a vehicle has received small series approval, then additional national/regional/local considerations, such as a need to inform fire services, may apply.

Legislation relevant to those involved in H_2 production, distribution, and retailing, particularly regarding HRS, is also surveyed and summarised. The main message that emerged is that as the amount of H_2 involved increases, so do RCS requirements.

Having identified wider EU legislative requirements, the relevant regional, national, and local laws and policies must also be considered. The final part of this sect A brief overview of national, regional, and local policies will then follow.

The report makes numerous references to EU *directives* and *legislation.* These are different because:

- EU directives must be implemented by member states to become binding.
- EU legislation are binding on all EU member states, irrespective of EU member states implementation.

As the HyTrEc2 project has exclusively focused on the use of compressed H_2 gas technologies in transport, cryogenic (liquid) H_2 legislation and standards are outside the scope of this report. Chemical storage of H_2 as either a liquid H_2 carrier or as a solid hydride are also outside the scope of this report.

Sections 5.2 to 5.5 focus on the H_2 elements of national legislation around Europe where this information was available, or relevant general elements of the national legislation, and for information includes direction to any National Policy Frameworks already available.

5.2 H2 Fuelled Vehicles, Including FCEVs

Vehicle manufacturers and converters need approval that their vehicles can be operated on public roads in the NSR. According to the UK Vehicle Certification Agency (VCA), *European Community Whole Vehicle Type Approval (ECWVTA) is based on the concept of 'type approval' and put simply; this process provides a mechanism for ensuring that vehicles meet relevant environmental, safety and security standards. As it is not practical to test every single vehicle made, one production vehicle is tested as being representative of the 'type'. A number of performance requirements will apply to a given vehicle type ranging from tyres through to exhaust emissions and braking systems. To ensure a consistent approach, the test methodology is outlined in the relevant EC Directive / Standards or UN ECE Regulation and the tests are carried out at an appropriate facility* [68]*.*

Approval and certification of H_2 vehicles is a nationally devolved activity [69]. However, type approval granted in one EU country must be accepted by the other EU countries. All EU countries have procedures and departments for providing approval for either small numbers of vehicles or type approval for a larger number of vehicles. The general principles covering the approval of vehicles for use on the roads in the NSR are closely related to EU legislation and directives and, as noted above, type-approval of a vehicle in one EU state should be valid in all EU nations. In practice, the German automotive sector has the most experience of H_2 vehicle type approval.

The following sections discusses certification and maintenance requirements for road vehicles, as well as specific requirements for cars, buses, motorcycles, and boats.

[68] European Community Whole Vehicle Type Approval (ECWVTA), VCA: https://www.vehicle-certification-agency.gov.uk/vehicletype/ecwvta-framework-directive.asp

[69] Hydrogen vehicle certification in detail in HyTEC Deliverable 5.7, *Report on the certification process for fleet use by hydrogen vehicles, P.Speers, 2013.*

5.2.1 Europe Wide Requirements for Certification and Approval for Use

Certifying that vehicles meet relevant legislation and standards is a crucial part of their deployment on the road and commercial roll out from a safety perspective for both the use of the vehicle and the interoperability of vehicles with refuelling stations.

- In terms of H_2 safety, the U -R134 is derived from the Global Technical Standards (GTR) 13 phase I: Global Technical Standards (GTR) 13, Global technical standards on H_2 and fuel cell vehicles (GTR 13) (ECE-TRANS-180a13e).

GTR1 was implemented at UN ECE R134. The development of GTR 13 phase II started in 2017. The 7th partner meeting minutes of the GTR project indicates that the EU will adopt GTR Phase II, and compliance will be mandatory from 2022 onwards[70]. There is no European-wide requirement for vehicles that aren't built on a sufficient scale to merit type-approval. Approval for small numbers of vehicles tends to be left to national requirements. The (EU) 2018/858, the new Type Approval Framework Regulation, is scheduled to come into effect from the 1st of September 2020, and has some cross references (for non-standard H_2 vehicles) and refers the reader back to the Standards (EC) No 79-2009 EC

Maintaining the vehicle is critical for safe operation, and refuelling, of H_2 vehicles. There are two European maintenance requirements for H_2 vehicles:

- There is a passing reference to the need for visual inspections of the fuel tank and pipes of H_2 vehicles over a pit or on a hoist in Directive 2014/45/EU of the European Parliament and of the Council of 3 April 2014 on periodic roadworthiness tests for motor vehicles and their trailers, see 6.1.3 of the table in Annex I (according to this directive, leak detection devices are not required for H_2 systems, whereas they are for other alternative fuels) – this Directive should be transposed into national legislation and applied by 20 May 2018.
- The requirements for vehicle manufacturers of type-approved vehicles to provide information for periodic inspection, see Article 4 clause 5 of Standards (EC) No 79/2009 and Annex I, part of Standards (EU) No 406/2010.

5.2.2 Cars, Buses and Trucks

Road vehicles of class M and N in Europe that are type-approved conform to the following legislation:

- Standards 406-2010 EC implementing Standards 79-2009 EC on type-approval of H_2-powered motor vehicles or the regulation. This legislation was repealed in 2019 and will no longer be valid after July 2022.
- UN ECE R134, Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of H_2-fuelled vehicles (HFCV) (ECE/TRANS/WP.29/2014/78). This is implanted in the EU as

It should be noted that Standards 406-2010 EC implementing Standards 79-2009 EC apply to liquid H_2 vehicles. UN ECE R134 applies to compressed gas H_2 vehicles.

[70] https://globalautoregs.com/meetings/1416-gtr13-session-7-4-7-nov-2019

The type-approval of cars, buses and trucks is highly harmonised. The following key legislation is of interest:

- Standards 79-2009 EC on type-approval of H_2-powered motor vehicles and amending Directive 2007 46 EC. The Standard was repealed in 2019 and will no longer be valid after 2022.
- Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles.
- Standards (EC) No 79/2009 Of the European Parliament and of the Council Of 14 January 2009 on Type-Approval of H_2 Powered Motor Vehicles, and Amending Directive 2007/46/EC.
- Commission Standards (EU) No 406/2010 of 26 April 2010 implementing Standards (EC) No 79/2009 of the European Parliament and the Council on type-approval of H_2-powered motor vehicles.
- Commission Standards (EC) No 692/2008 of 18 July 2008 on type-approval of motor vehicles for emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and access to vehicle repair and maintenance information.
- Commission Standards (EU) No 630/2012 of 12 July 2012 amending Standards (EC) No 692/2008, as regards type-approval requirements for motor vehicles fuelled by H_2 and mixtures of H_2 and natural gas with respect to emissions, and the inclusion of specific information regarding vehicles fitted with an electric power train in the information document for the purpose of EC type–approval.
- Council Directive 1999/37/EC of 29 April 1999 on the registration documents for vehicles.
- Commission Directive 2003/127/EC of 23 December 2003 amending Council Directive 1999/37/EC on the registration documents for vehicles.
- Directive 2014/45/EU of the European Parliament and of the Council of 3 April 2014 on periodic roadworthiness tests for motor vehicles and their trailers.
- Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles (Clean vehicle directive).
- The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR).
- Directive 2008/68/EC of the European Parliament and of the Council of 24 September 2008 on the inland transport of dangerous goods.
- Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure (AFID).

5.2.3 Bikes, Motorcycles and Quadracycles

As with other categories of road going motor vehicles, the type-approval of two or three-wheeled vehicles is highly harmonised. The general framework for all vehicles is common while specificities, at EU level, are dealt with in Standards (EU) No 168/2013 and Commission Delegated Standards (EU) No 134/2014.

- Standards (EU) No 168/2013 of the European Parliament and of the Council of 15 January 2013 on the approval and market surveillance of two– or three-wheel vehicles and quadricycles.
- Commission Delegated Standards (EU), No 134/2014 of 16 December 2013, supplementing Standards (EU) No 168/2013.
- Directive 2014/45/EU of the European Parliament and of the Council of 3 April 2014 on periodic roadworthiness tests for motor vehicles and their trailers.
- Council Directive 1999/37/EC of 29 April 1999 on the registration documents for vehicles.
- Commission Directive 2003/127/EC of 23 December 2003 amending Council Directive 1999/37/EC on the registration documents for vehicles.
- Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles (Clean vehicle directive).

5.2.4 Boats and Ships

Shipping legislation are generally established at the international level (IMO)[71]. At EU level, Directives 2014/90/EU on marine equipment; 2009/45/EC on safety legislation and standards for passenger ships and 2009/16/EC on port state control are the most relevant legislative sources specific to boats and ships. ATEX Directive (2014/34/EU), as well as the Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres and Directive 2012/18/EU on the control of major accident hazards involving dangerous substances (Seveso III), remain relevant for certain activities (landing and bunkering for example.)

- Directive 2014/90/EU of the European Parliament and of the Council of 23 July 2014 on marine equipment.
- Directive 2009/45/EC of the European Parliament and of the Council of 6 May 2009 on safety legislation and standards for passenger ships.
- Directive 2009/16/EC on port State control and Directive 2013/38/EU amending Directive 2009/16/EC on port State control.
- Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major accident hazards involving dangerous substances (so-called SEVESO Directive).
- ATEX Directive 2014/34/EU - covering equipment and protective systems intended for use in potentially explosive atmospheres.
- Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.

In addition, it should be noted that when installing hydrogen into marine applications as a power source, vessels must be classified by an accredited certification body. For example, DNV-GL have direct experience in certifying hydrogen propulsion for marine applications and have written guidance in place: DNV GL-RU-SHIP Pt.6 Ch.2 Sec. 3. – Fuel Cell Installations July 2019[72].

5.3 Hydrogen Production and Storage

The storage and production of H_2 are affected by some of the same legislation. The SEVESO Directive (above five tonnes of H_2), the ATEX (above one tonne of H_2) and Pressure Equipment Directives apply. Together these impose obligations on operators and manufacturers of equipment. The SEA and EIA Directives would also apply, subject to national conditions (for example, above 5 tonnes of H_2 storage.) Environmental, as well as safety and health requirements, may apply; however, these are not H_2 specific. Some of the key environmental and health & safety legislation are:

- Directive 2006/42/EC of 17 May 2006 on machinery Directive 2014/35/EU relating to electrical equipment designed for use within certain voltage limits.
- Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (in force).
- Standards (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures.
- Directive 2009/104/EC concerning the minimum safety and health requirements for the use of work equipment by workers at work.
- Council Directive 89/654/EEC concerning the minimum safety and health requirements for the workplace.

[71] IGF, International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels http://www.imo.org/en/OurWork/Safety/SafetyTopics/Pages/IGF-Code.aspx

[72] Legislation for Classification: Ships https://legislation.dnvgl.com/docs/pdf/DNVGL/RU-SHIP/2020-07/DNVGL-RU-SHIP-Pt1Ch1.pdf

- Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers.

The use of H_2 as a fuel should also consider the following key documents:

- Directive (EU) 2015/652 - establishing the legally binding efficiency factor of H_2 fuel cell electric powertrains (0,4) and the GHG intensity of Compressed H_2 in a fuel cell (expressed in g CO_2eq/MJ) produced by various methods.
- Directive 2009/28/EC on the promotion of the use of energy from renewable sources (RED).
- Directive 98/70/EC relating to the quality of petrol and diesel fuels (and its subsequent amendments) incentivises the use of low carbon intensity fuels (including H_2).

5.3.1 SEVESO Directive

The SEVESO Directive is **Directive 2012/18/EU (and its subsequent amendments) of the European Parliament and of the Council of 4 July 2012 on the control of major accident hazards involving dangerous substances**. The Directive covers situations where dangerous substances may be present (e.g. during processing or storage) in quantities exceeding certain limits. **For quantities of less than 5 tonnes of H_2, none of the SEVESO obligations would apply**. The entirety of the SEVESO applies for H_2 stored in quantities of 5 tonnes or greater. Particular attention should be paid to the following articles:

- General obligations on the operator (Article 5).
- Notification (information on the form and amount of substances, the activity, and the surrounding environment) of all concerned establishments (Article 7).
- The obligation to deploy a major accident prevention policy (Article 8).
- The obligation to produce a safety report for upper-tier establishments (Article 10).
- The obligation to produce internal emergency plans for upper-tier establishments (Article 12).
- Authorities to exert control of the siting of new establishments, modifications to new establishments, and new developments including transport routes, locations of public use and residential areas in the vicinity of establishments, (Article 13).
- The obligation to conduct public consultations on specific individual projects that may involve the risk of major accidents (Article 15).
- Annex I, Part 1, of the directive establishes H_2 as a dangerous substance (therefore within scope) and lists the quantity of H_2 for the application of lower-tier requirements (≥ 5t) and upper-tier requirements (≥ 50 t).

5.3.2 ATEX Directive

ATEX Directive is the term applied to two separate directives:

- **ATEX 95 equipment directive 94/9/EC, Equipment and protective systems intended for use in potentially explosive atmospheres**.
    - The new ATEX 2014/34/EU came into force in April 2016.
- **The ATEX 137 workplace directive 99/92/EC, Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres**.

The ATEX Directives (and their subsequent amendments) defines the essential health and safety requirements and conformity assessment procedures (Article 4) to be applied before products are placed on the EU market. ATEX Directives are significant for the engineering of H_2 production plants. ATEX Directives applies to equipment and protective systems intended for use in potentially explosive atmospheres.

The Directive requires employers to classify areas where hazardous explosive atmospheres may occur into zones. The classification is given to a particular zone, and its size and location depend on the likelihood of an explosive atmosphere occurring and its persistence if it does. The Directive requires the manufacturers to design their equipment to be suitable for use within their customer's explosive atmosphere. Therefore, manufacturers of equipment rely upon their customer to give them information about the classification of the zone and the flammable substance(s) within that zone. The Directive describes the legislation and standards for all actors in the value chain, with the aim of ensuring that only safe equipment for use in potentially explosive atmospheres is sold and applied. It provides legislation as to how equipment shall be constructed, produced, and documented, as well as the legislation for CE-labelling. Of relevance to H_2 technologies are:

- Conformity assessment procedures - Article 13.
- EU declaration of conformity - Article 14.
- General principles of the CE marking - Article 16.

Analysis of ATEX documentation and legislation will quickly highlight the need for identifying "ATEX zones":

- Zone 0: a location in which an ATEX is present continuously or for long periods or frequently.
- Zone 1: a location in which an ATEX is likely to occur in normal operation occasionally.
- Zone 2: a place in which an ATEX is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Where necessary, places where ATEX's may occur in such quantities as to endanger the health and safety of workers shall be marked with appropriate signs at their points of entry. Typically, well-designed H_2 transport solutions will not store H_2 in sufficient quantities to require ATEX compliance. In those few instances where ATEX compliance is required, ZONE 2 will be the typical ATEX standard to comply with.

5.3.3 Pressure Equipment Directive

Directive 2014/68/EU (and its subsequent amendments) of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.

The Pressure Equipment Directive (PED) applies to the design, manufacture and conformity assessment of pressure equipment and assemblies with a maximum allowable pressure greater than 0.5 bar. Technical requirements and classification according to an ascending level of hazard, depending on pressure, volume or nominal size, the fluid group and state of aggregation, as well as conformity assessment procedures are laid down and required by the Directive. H_2 is a fluid which falls under Group 1. Group 1 consists of dangerous fluids (flammable, toxic and oxidising). As a result, a large part of the equipment for H_2 production, storage and distribution must meet the technical requirements set out in the PED.

5.3.4 Industrial Emissions Directive

Directive 2010/75/EU of the European Parliament and the Council on industrial emissions. The industrial emission directive requires the use of the best available techniques to ensure the protection of human health and the environment. Annex I of the directive lists industrial processes which require a permit from the appropriate member state to be allowed to operate. Depending on the method of H_2 production, annex I C-102, D-102 and G-103 of the directive and may apply.

5.3.5 Strategic Environmental Assessment

The Strategic Environmental Assessment to the Convention on Environmental Impact Assessment (SEA) is a regulatory planning tool applied at the national and regional level. The UNECE (United Nations Economic Commission for Europe) regulate the SEA. There is a homogenised EU version of the SEA, also known as the Strategic Environmental Assessment. The SEA focuses on health and environmental issues at the planning and policy level. The SEA is designed to prevent unwanted health and environmental consequences at the earliest stages of governmental policy and planning procedures. Individual projects are unlikely to be impacted directly by the SEA itself. However, the SEA should have been used in the development of local and regional policies and procedures which individual projects will have to comply. The administration and implementation of environmental impact assessments are key outputs of the SEA. This includes the Environmental Impact Assessment (EIA) which is the project-specific policy document to which larger H_2 transport projects must comply.

5.3.6 Environmental Impact Assessment Directive

The Environmental Impact directives (and their subsequent amendments) came into force in 1985 and applied to both public and private projects. Annex I of the directive mandates which projects must complete an EIA. Annex II lists other projects for which local or regional authorities may require the completion of an EIA. Define a strategic environmental impact assessment procedure for those developing and deploying sites, projects or technologies that may have wider environmental impacts.

In summary, the developer may request that the competent authority define the scope of the EIA information to be provided (scoping stage). The developer must provide information on the environmental impact (EIA report – Annex IV) The environmental authorities and the public (and affected Member States) must be informed and consulted; the competent authority decides if the project, development or technology deployment may go ahead. This decision must take into consideration the results of consultations. The public is informed of the decision afterwards and can challenge the decision before the courts. In line with the EIA Directive, Production and Storage of H_2 falls within the projects listed in Annex II of the directive (6a and 6c - production of chemicals; and storage facilities for chemical product), for which Member States shall determine whether the project shall be made subject to an assessment or not. In some EU countries, storage of 5 tonnes of H_2 or more falls within the scope of the Directives. The latest amendment, (Directive 2014/52/EU) introduces minimum requirements with regards to the type of projects subject to assessment, the main obligations of developers, the content of the assessment and the participation of the competent authorities and the public. Depending on the application, and locations of any proposed H_2 project, the following environmental legislation should be considered when writing environmental impact assessments:

- Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment.
- Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (EIA Directive).
- Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment (SEA Directive).
- Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and wild fauna and flora.
- The Convention on the Conservation of European Wildlife and Natural Habitats (Article 6) on the assessment of plans or projects not connected with the management of, but likely to have a significant effect on the conservation objectives of Natura 2000 sites.
- Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. The provisions of the Directive include the identification and classification of Special Protection Areas (SPAs) for rare or vulnerable species and the establishment of a general scheme of protection for all wild birds (Article 5). They further define the conditions under which permission may be granted for otherwise prohibited activities.

5.3.7 The Revised Renewable Energy Directive (RED II)

The revised renewable energy directive (RED II) legislates that the share of renewable energy in the transport sector is **at least 14% by 2030.** RED II also contains provisions for the establishment of Guarantees of origin schemes for renewable H_2.

5.4 Hydrogen Transport & Distribution

The transport and distribution of H_2 are wide number of agreements, legislation, and restrictions. There are multiple agreements concerning the International Carriage of Dangerous by road, rail, water, or air. classification, labelling and packaging of substances (CLP) and Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation applies to the transport of H_2. If H_2 is transported as a pressurised fluid, transport of pressurised equipment directives also applies. A summary of the relevant legislation follows.

5.4.1 ADR and ADR 2019: The European Agreement concerning the International Carriage of Dangerous Goods by Road

(ADR) has been revised and consolidated in January 2019. The revised ADR document is referred to as "ADR 2019" and published as document ECE/TRANS/275, Vol. I and II. When dangerous goods are transported, the driver of the vehicle is required to carry certain documents, including instructions in writing for the dangerous goods (a four-page document which must be available at all times) and the drivers Vocational Training Certificate (specific to the class of dangerous goods being carried).

5.4.2 ADN and RID: European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways

(ADN), is part of the UN Recommendations on the Transport of Dangerous Goods (H_2 is classified as a “Division 2.1 - Flammable gas” in the UN system). The **standards concerning the International Carriage of Dangerous Goods by Rail** (RID) applies to the international transport of dangerous goods by rail. The affiliated countries come to a mutual agreement, as discussed above for the ADR.

ADR, RID and ADN lay down uniform legislation for the safe international transport of dangerous goods, these legislations harmonise national transport legislation across the EC and ensure the proper functioning of the common transport market. These legislations inform the transport of dangerous goods directive.

5.4.3 TDG: Directive 2008/68/EC on the inland transport of dangerous goods

(Article 1), applies to the transport of dangerous goods by road, by rail or by inland waterway within the EC, includes loading, unloading, transfer between modes of transport and stops during transport.

5.4.4 SOLAS, MARPOL and IMDG

The minimum safety standards for all international merchant shipping are set in the **International Convention for the Safety of Life at Sea** (SOLAS). **The International Convention for the Prevention of Pollution from Ships** (MARPOL), 1973 as modified by the Protocol of 1978 (also known as MARPOL 73/78) is a maritime environmental standard complied with by all 156 registered maritime flag-states. The SOLAS and MARPOL regulation, in turn, form the basis of the **International Maritime Dangerous Goods** (IMDG). The IMDG must also be complied with when considering multi-modal transport of goods. IMDG requirements for North Sea shipping must interface seamlessly with ADR, RID or ADN legislation.

5.4.5 Safe Transport of Dangerous Goods by Air

The International Civil Aviation Organization (ICAO) administers and regulates the **Technical Instructions for the Safe Transport of Dangerous Goods by Air**. The majority of H_2 transportation will be a Class 2 hazard. Before transport, the organisation delivering H_2 by aircraft must complete Civil Aviation Authority (CAA) Form SRG 2805, submit the appropriate fee using Payment Form SRG 2812 and send to the CAA Dangerous Goods Office. Details of costs can be found in the CAA Scheme of Charges - Air Operator and Police Air Operator Certificates. This process may have to be completed for each state the aircraft passes over, as well as the country where the aircraft lands or takes off.

5.4.6 CLP: The Harmonized European Standards (EC) No 1272/2008 on classification, labelling and packaging of substances.

The CLP Standards includes H_2 as a hazardous substance (Part 3, Table 3.1) and establishes legislation for classification and labelling of H_2 (Annex VI).

5.4.7 REACH: Registration, Evaluation, Authorisation and Restriction of Chemicals

The REACH legislations are the Commission Standards (EU) No 453/2010 (amending Standards (EC) No 1907/2006) on the **Registration, Evaluation, Authorisation and Restriction of Chemicals** (REACH). REACH applies to substances manufactured or imported into the EU in quantities of 1 tonne or more per year, but specifically excludes the transport of substances. REACH adopts and builds on the previous 'safety data sheet' (SDS) system, and all safety data sheets should comply with the REACH legislations. The correct layout and contents of SDS are detailed in Annex II of the REACH Standards (EU) 2015/830 (and its subsequent amendments).

REACH safety data sheets would not be required for the transport of H_2 but is required for the production, storage and dispensing of H_2 in amounts greater than 1 tonne. All such production facilities must be registered in the REACH database. However, a properly constructed SDS will include a section transportation information (based on United Nations standards). In section 14, including specific transportation requirements for the International Civil Aviation Organization (ICAO), 49CFR, and the International Maritime Dangerous Goods (IMDG) Code. Therefore, even though the legal requirement for documentation on emergency procedures for the transport of dangerous chemicals does not require REACH compliant SDS to travel with the shipment, it is strongly recommended that SDS for H_2 accompany all H_2 shipments in addition to the required hazardous goods transportation documents as per the ADR 2019 requirement.

5.4.8 PED and TPED: The Pressure Equipment Directive and the Transport of Pressure Equipment Directive

The **Pressure Equipment Directive** and the associated **Transport of Pressure Equipment Directive** combine with the ADR 2019 legislations. These three sets of legislations together define the limitations of pressurised H_2 transport across the EC. The safety factors of the ADR 2019 and the restrictions of TPED ensure that the volume of H_2 receptacles is restricted to either 450 litres or 3000 litres. The PED defines five levels of hazard, with level five being the most hazardous.

Pressurised H_2 cylinders typically use pressures and volumes of H2 that make them a Class IV hazard under the PED legislations. It has been observed that high safety factors, stipulated by ADR and TPED restrict the practical limits of H_2 receptacles to 450 kg gaseous or 3000 kg liquid for traditional transport technologies. Higher pressure trailers, utilising novel materials and cylinder designs can transport significantly larger mass of H_2 at higher pressures. These new-material cylinders still comply with ADR and TPED safety factors. The interplay of ATEX, TPED, ADR and vehicle design legislations typically limit steel cylinder or tube-trailer H_2 transport to 1,000 kg per vehicle.

5.5 Hydrogen Refuelling Stations

At the time of writing, RCS for H_2 refuelling stations in Europe are still under development. However, the implementation of the Alternative Fuels Infrastructure Directive 1, (referred to as the AFID) has brought a degree of standardisation to HRS around Europe.

5.5.1 Alternative Fuels Infrastructure Directive

Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure (AFID) sets the minimum requirements for implementing alternative fuels infrastructure. Article 5 states that countries with plans for H H_2 mobility ensure that an appropriate H_2 infrastructure is in place to ensure the circulation of H_2-powered motor vehicles by 2025. Annex II contains technical specifications for H_2 refuelling points for motor vehicles. Outdoor HRS must comply with the technical specifications of the ISO/TS 20100 Gaseous H_2 Fuelling specification. ISO/TS 20100 includes fuelling algorithms and equipment.

Connectors must comply with ISO 17268 gaseous H_2 motor vehicle refuelling connection devices standard. The H_2 dispensed must comply with the technical specifications included in the ISO 14687-2 standard. Several other significant pieces of legislation must also be considered:

- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (RED).
  - Mandatory national targets for renewable energy contributions.
- Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources (Indirect Land Use Change (ILUC) Directive).
  - Renewable liquid and gaseous transport fuels of non-biological origin.
- Directive 98/70/EC of the European Parliament and of the Council of 13 October 1998 relating to the quality of petrol and diesel fuels and amending Council Directive 93/12/EEC (FQD).
- Fuels with low life cycle greenhouse gas emissions per unit of energy as well the use of carbon capture and storage.
- Directive 2009/30/EC of the European Parliament and of the Council of 23 April 2009 amending Directive 98/70/EC as regards the specification of petrol, diesel and gasoil and introducing a mechanism to monitor and reduce greenhouse gas emissions.
- Article 7a of Directive 2009/30/EC requires suppliers to reduce life cycle greenhouse gas emissions per unit of energy from fuel and energy supplied by 6 % by 31 December 2020. It also recommends an additional 2% reduction through any possible technologies.

The AFID required European countries with H_2 infrastructure to ensure that publicly accessible H_2 refuelling points deployed (or renewed) from the 18th November 2017 will comply with a set of named standards. A National Policy Framework must be generated by each country in the European Union to explain how the uptake of “Alternative Fuelled Vehicles” is envisaged in the foreseeable future.

5.5.2 Dispensing

H_2 refuelling stations (HRSs) are required to dispense H_2 to vehicles. The key legislations for HRSs are clearly defined and agreed by all NSR regions:

- HRSs are legislated for in the ISO 19880 family of protocols and standards.
- Unified ISO standards recently published include local authority ‘checklists’ for approval.
- **PD ISO/TS 19880-1:2016** (Gaseous Hydrogen — Fuelling stations: Part 1: General requirements).
- **SAE J2601** (Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles).
- **SAE J2799** (Hydrogen Surface Vehicle to Station Communications Hardware and Software).

However, as previous researchers have highlighted “*…while there is commonality in terms of the overall EU directives that are followed in each country, there are differences in the processes and involved in HRS permitting and installation, despite the continued evolution of H_2 refuelling RCS such as SAE J2601 and ISO/TS 19880.*”[73].

Measurement of small amounts of dispensed H_2 requires greater accuracy than is typically experienced in many HRS installed for passenger vehicles to date. Projects such as MetroHyVe are actively looking at this topic.

[73] D5.19; H2ME; Hydrogen Refuelling Stations Safety, Regulations, Codes and Standards : Lessons Learned, P. Speers 2018

5.5.3 General European Legislation Relevant to HRS

In addition to the AFID related requirements coming into force on the 18th November 2017, existing general health and safety legislation or legislation relevant to the CE marking of HRS put on the market in Europe, that are applicable to H_2 refuelling stations across Europe include the following EU Directives, implemented as national legislations in each EU country (Note: not a comprehensive list – other Directives may apply):

- **Directive 99/92/EC** on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres - also known as 'ATEX 137' or the 'ATEX Workplace Directive'.
- **Directive 2006/42/EC** of the European Parliament and the Council of 17 May 2006 on machinery and amending Directive 95/16/EC - The Machinery Directive.
- **Directive 2010/75/EU** of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) – The Industrial Emissions Directive.
- **Directive 2012/18/EU** of the European Parliament and of the Council of 4 July 2012 on the control of major accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC - also known as Seveso III.
- **Directive 2014/30 EU** of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (replacing 2004/108/EC) - The EMC Directive.
- **Directive 2014/34/EU** of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective
- systems intended for use in potentially explosive atmospheres (replacing Directive 94/9/EC) - also known as 'ATEX 95' or 'the ATEX Equipment Directive'.
- **Directive 2014/35/EU** of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits (replacing Directive 2006/95/EC) - The Low Voltage Directive.
- **Directive 2014/68/EU** of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment (replacing Directive 97/23/EC) - The Pressure Equipment Directive (PED).

5.5.4 Developments in Standardisation for Hydrogen Refuelling Stations in Europe

In response to the European Mandate M533, several standards on the interoperability of H_2 refuelling stations with H_2-fuelled vehicles are being written in the CEN committee CEN TC 268. It is anticipated that these will take the place of the current references in Annex II, clause 2 (ISO/TS 20100, ISO 14687-2, and ISO 17268), however this will not be amended prior to November 2017:

- ISO/TS 20100 (2008) was a development document defining the general requirements for HRS, prepared on the path towards developing an ISO standard for H2 refuelling stations. There are aspects of this document that have either become outdated, as technology and understanding has progressed, or where further detail is necessary. This is being addressed by the preparation of ISO 19880-1 in ISO TC 197 WG24, anticipated in 2018-2019. A stepping stone in the development process of this standard was the publication of ISO TS19880-1 in 2016. The ISO 19880-1 (and the predecessor ISO/TS 20100) cover a wide range of aspects of the design, operation, and maintenance of HRS.
    - ISO 19880-1:2020(en)Gaseous H2 — Fuelling stations — Part 1: General requirements was published in March 2020
- In parallel, the development of a document at CEN level that is more focused on the requirements needed to ensure interoperability is being carried out in CEN TC 268 WG5. This will be closely aligned with the forthcoming ISO 19880-1. The European standard will be numbered EN 17127.
- ISO 14687-2 covers the quality of H2 dispensed by HRS. This document, published in2012 by ISO TC 197, is currently under development in ISO TC 197, to be published as ISO14687. However, this is not anticipated until 2018-2019.

- As a result, a parallel document is being developed as a European Norm by CEN TC 268 WG5.
- to be aligned, as far as possible, with the revision of ISO 14687. This will also include the relevant elements of another H2 quality-related standard, being developed as ISO19880-8. The European standard will be numbered EN 17124.
- ISO 17268 covers the requirements for the interface between the dispenser and the vehicle, i.e. the nozzle and receptacle. This document, published in 2012 by ISO TC 197, has also recently been published as EN ISO 17268: 2016, which is identical to the original ISO document, due to the time limitation of the Mandate M533. ISO 17268 is under development within ISO TC 197 WG5 to bring it in line with the Society of Automotive Engineers (SAE) standard SAE J2600, however it would not have been ready in time for the December 2016 deadline given by the EC. Once revised, it is anticipated that the document will be developed into a European Norm and replace the EN ISO 17268: 2016. (It is worth noting that there is no interoperability issue at the moment due to the compatibility of SAE J2600 compliant nozzles and vehicle receptacles with their respective ISO 17268 equivalents, and also worth noting that the majority, if not all, vehicles use SAE J2600 compliant receptacles).

So, while the development of standards relating to HRS is ongoing in the CEN TC 268, the AFID is being transposed into national legislation in a variety of manners.

5.6 NSR regional variations to EU legislations and directives

Any NSR H_2 vehicles, dispensers, transporters, storage, and production equipment, should comply with the relevant EU legislation, introduced in the preceding section of this report. **In addition to EU legislations on H2 transport and the carriage of dangerous goods; the following limits should also be complied with for those vehicles operating on H2 or delivering H2 supplies in and around individual countries in the North Sea Region.**

Table 3 is a summary of the most stringent H2 specific legislations in NSR countries (more stringent than basic EU legislations)

	Value	Country/ region	Notes
Minimum volume or mass of H_2 that requires planning, permitting or other official notification	10 litres 40 kg	Sweden UK	UK: 2 tonnes maximum amount of H_2 permitted on site without H_2 specific planning notification; 2% of this value (40 kg) is the "*de minimis*" reporting level.
Upper mass of stored H_2	200 kg	Germany and Sweden.	Maximum permitted mass stored in a single "tube" or tank
Upper pressure of stored H_2	200 bar.	Norway and Netherlands	Maximum permitted pressure for transportation in steel tanks.
Safety factors required	Greater than three.[74]	Germany.	

Table 3: Additional H2 requirements in the NSR beyond EU legislations and directives

[74] PED 3.2.2 and 7.4 specify the safety coefficient of hydraulic tests at sf=1.43.

6 NSR Regulatory Requirements

Chapter six of this report presents and 'easy reference' tabulated list of national legislation and standards by country. Topics covered include H_2 production, H_2 transport and distribution, HRS construction and operation, and H_2 vehicles. In each of the NSR countries, existing **EU legislation and directives still apply and must be adhered to, in addition to individual country's specific legislation**. The key regulatory requirements surrounding H_2 production, transport and distribution, construction, and operation, and finally H_2 vehicles were discussed section 4. The information is presented as an EU wide regulatory 'data card'. NSR country specific data cards for each NSR country are also presented.

Readers of this document are advised to read, and where appropriate, apply all EU legislations, as well as any national legislation that applies to their organisation's operations.

In all NSR countries the following EU legislations are of particular importance:

6.1 EU H2 regulatory summary

Table 4 is a summary of key EU legislation relating to H2 transport economy topics.

EU regulatory H_2 data card	
H_2 Production	SEVESO Directive, the ATEX Directive and Directive 2010/75/EU on industrial emissions place important obligations on the producers of H_2, and on equipment manufacturers. The strategic environmental assessment (SEA) and environmental impact assessment (EIA) directives apply indirectly to H_2 production (Annex II 6a and 6c - production of chemicals; and storage facilities for chemical product). National legislation will determine if an EIA is required or not. Directive 99/92/EC ('ATEX 137' or the 'ATEX Workplace Directive') on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres. Directive 94/9/EC ('ATEX 95' or 'the ATEX Equipment Directive') on the approximation of the laws of Members States concerning equipment and protective systems intended for use in potentially explosive atmospheres.
H_2 Transport & Distribution	H_2 is transported in a variety of phases and states (liquid, gaseous, adsorbed onto the surface of another material, absorbed through the bulk of another material or chemically bound in another form) , and is typically transported in tanks (sometimes referred to as 'tubes') or cylinders. H_2 is subject to the legislations on the transport of dangerous goods by road, by rail or by inland waterway within or between Member States. The European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) classifies tunnels alphabetically. Flammable gasses are classified as 'UN class 2.1 flammable gas' when stored as a compressed gas in cylinders. Compressed H_2 is specified as UN1049. In accordance with 1.1.3.6 of ADR; flammable gasses of less than 333 litres, based on the water storage volume of the cylinder, or 333 kg of liquid H_2, section 1.1.3.6 of ADR (sometimes referred to as 'ADR light'[75]) applies. If the 333 litres (or 333 kg for liquids) threshold for UN class 2.1 substances is exceeded, the full ADR compliance is required, including specialised driver training, orange plates must be displayed, and tunnel restrictions apply. For quantities greater than 333 litres (or 333 kg for liquified H_2) A, B and C class tunnels can transport H_2. Class D and E class tunnels cannot have quantities greater than 333 litres (or 333 kg for liquified H_2) pass through them. It should be noted that some

[75] https://www.rearosupplies.co.uk/images/source/en-transporting-cylinder-gases-by-road.pdf

	tunnels change class at certain times of day and may place additional limits on the amount of H_2 that can be transported through them. Directive 2008/68/EC on the inland transport of dangerous goods and the UN agreements on which it is based (ADR, RID and AND). Directive 2010/35/EU on transportable pressure equipment refer to the assessment of transportable cylinders, tubes, cryogenic vessels, and tanks for transporting gases. Standards 453/2010/ EU (as part of the REACH) impacts the transportation of H_2, making H_2 subject to the use of safety data sheets[76].
H2 Vehicles	Council Directive 1999/37/EC on the registration documents of vehicles. Directive 1999/37/EC, amended by Directive 2003/127/EC, and Standards (EC) No 692/2008) set the general framework for the type approval while more recent, legislative acts (e.g. Standards (79/2009 Commission Standards (EU) No 406/2010) extend the provisions specifically to H2 powered vehicles. Note that Vehicle registration requirements and procedures are subject to National law. The movement of H2 vehicles on European Roads is regulated by The European Agreement concerning the International Carriage of dangerous Goods by Road (ADR) and Directive 2008/68 on the inland transport of dangerous goods. European Parliament and Standards (EC) 406/2010 of the Council on type-approval of H_2-powered motor vehicles define requirements for H_2 vehicles in conjunction with Standards (EC) No. 79/2009, directive EU406/2010, and EU Standards 168/2013 for motorbikes. UN Standards No. 134 on uniform provisions concerning the approval of motor vehicles and their components concerning the safety-related performance of H_2-fuelled vehicles applies. Directive 2007/46 establishes a framework for the type approval of motor vehicles classes M (passenger cars and busses), N (trucks), O (trailers), and of systems and components intended for such vehicles. The UNECE Legislations listed in Part II of Annex IV are recognized as being equivalent to the corresponding separate directives or legislations in as much as they share the same scope and subject matter The Directive 2007/46 is substantially transposed in all NSR countries. Directive 2009/33 (Clean vehicles Directive) briefly considers incentives for H_2 vehicles There is no EU legislation regulating the service and maintenance requirements and procedures for H_2 vehicles. National bodies may have published some guidelines. Generally, vehicle manufacturers publish guides for maintenance and service of the vehicles.

Table 4: summary of key EU regulation

[76] https://www.hylaw.eu/sites/default/files/2019-02/D4.4%20-%20EU%20regulations%20and%20directives%20which%20impact%20the%20deployment%20of%20FCH%20technologies_0.pdf

<table>
<tr><th colspan="2">Norway H2 Data card</th></tr>
<tr><td>H2 Production</td><td>Land use & zoning is covered by the Norwegian planning and building act. The standard inflammable gas legislation apply.
The local municipality is responsible for the permit process, with local fire and rescue agencies possibly invited into the decision-making process. Local variations may apply.
1. Proposed site for H2 production must be announced publicly for six weeks to allow public involvement, feedback is received and planning committee decides within 24 weeks of first application.
2. Initial permit, followed by permit to start construction required.
3. Maximum application time should be 42 weeks.
4. Operations permit is required before commencing H2 production.
For quantities exceeding 5 tonnes production the major accident standards applies and special permission from the Directorate for Civil Protection is required.</td></tr>
<tr><td>H2 Transport & Distribution</td><td>The key legislation governing H2 transport and distribution in Norway is the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR).
Access limitations for transporting H2 are as follows.
• If transporting class 2 tanked H2, forbidden to enter category B, C, D & E tunnels.
• If transporting H2 in cylinders, may enter category B & C.
• Some special timing restrictions apply, such as the tunnel between Ellingsøy and Valderøy which is a category C between 0600 – 2400. Tunnels may also require closure to the public for dangerous goods to transit through, such as in Hvalar.
• Busy urban streets may have time limited restrictions for dangerous goods (specifically Oslo).
• If transporting on ferry, must be an open ferry with on board foam fire suppressant.
Quantity limits require a maximum of 300 litres, and pressure must be 200 bar, meeting ECE standards No.67 Revision 2, No. 110 Revision 12, No 115 or No 79/20094 in combination with EU Standards No. 406/20105.
A permit is required for a specified route to be able to transport H2. The Directorate for Civil Protection are responsible for the transport of dangerous good and ADR compliance. Whilst the Norwegian Public Roads Administration allocate routes and ADR driver/vehicle certification and control. ADR and PED compliance is required, with additional requirements being potential parking stops enroute at the request of municipal fire and rescue departments.</td></tr>
<tr><td>HRS Construction & Operation</td><td>Key legislation for construction and operations are ISO 14687, ISO 14687–2:2012(EN) Part 2, SAE J2719 (2015) and Directive 2014/94/EU. An initial general permit is required as well as an operational permit and a construction permit. Application time is generally 8 months. Special case permits are required from the Directorate for Civil Protection for H2 tanks above 0.4 m3 or for tanks of greater than 5 tonnes. Applications for permits may need to be made to National Ministry of Local Government and Modernisation, the Climate and Pollution Agency and the Directorate for Civil Protection. In practice local municipalities may be able assist with all required permits.
ADR/RID agreements (8.2.1, ADR/RID 2017, Norwegian version) apply to delivery, production, and operations. Pressure containers must meet ECE Standards No. 67 Revision 2, ECE Standards No. 110 Revision 12, or ECE Standards No. 115 or Standards (EC) No. 79/20094 in combination of Standards (EU) No. 406/20105, as relevant. Tier 4 high pressure (520 bar) possible if standards are agreed going forward. 3000 litres is maximum permitted storage at a dedicated HRS.
For H2 fuel cell HRS, H2 purity required is 99.999%.</td></tr>
<tr><td>H2 Vehicles</td><td>Key legislation for H2 vehicles is ISO 14687–2, ISO 4687–2:2012 and SAE J2719_201511. There are no current restrictions on H2 vehicles in Norway, with incentives including the use of bus lanes, exemption from VAT (25%), registration fees and toll charges.
Type approval is completed by the Directorate of Public Roads, and vehicle registration by the Norwegian Public Roads Administration.</td></tr>
</table>

6.2 NSR country's hydrogen regulatory summary

Table 5 through Table 11 are 'Data card' summaries of key legislation permits and procedures relating to H2 transport topics in each of the NSR nations. Data cards are presented in the following order:

- Norway
- Sweden
- Denmark
- Netherlands
- Germany
- Belgium
- United Kingdom

Readers of this document are advised to familiarise themselves with local legislative, permitting and planning requirements for each NSR nation in which H_2 transport technologies will operate.

Norway H_2 Data card	
H_2 Production	**Land use & zoning** is covered by the Norwegian planning and building act. The standard inflammable gas legislation apply. The local municipality is responsible for the **permit process,** with local fire and rescue agencies possibly invited into the decision-making process. Local variations may apply. 5. Proposed site for H_2 production must be announced publicly for six weeks to allow public involvement, feedback is received and planning committee decides within 24 weeks of first application. 6. Initial permit, followed by permit to start construction required. 7. Maximum application time should be 42 weeks. 8. Operations permit is required before commencing H_2 production. For **quantities exceeding 5 tonnes** production the major accident standards applies and special permission from the Directorate for Civil Protection is required.
H_2 Transport & Distribution	The **key legislation** governing H_2 transport and distribution in Norway is the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR). Access limitations for **transporting H_2** are as follows. • If transporting class 2 tanked H_2, forbidden to enter category B, C, D & E tunnels. • If transporting H_2 in cylinders, may enter category B & C. • Some special timing restrictions apply, such as the tunnel between Ellingsøy and Valderøy which is a category C between 0600 – 2400. Tunnels may also require closure to the public for dangerous goods to transit through, such as in Hvalar. • Busy urban streets may have time limited restrictions for dangerous goods (specifically Oslo). • If transporting on ferry, must be an open ferry with on board foam fire suppressant. **Quantity limits** require a maximum of 300 litres, and **pressure** must be 200 bar, meeting ECE standards No.67 Revision 2, No. 110 Revision 12, No 115 or No 79/20094 in combination with EU Standards No. 406/20105. A **permit** is required for a specified route to be able to transport H_2. The Directorate for Civil Protection are responsible for the transport of dangerous good and ADR compliance. Whilst the Norwegian Public Roads Administration allocate routes and ADR driver/vehicle certification and control. ADR and PED compliance is required, with additional requirements being potential parking stops enroute at the request of municipal fire and rescue departments.
HRS Construction & Operation	**Key legislation** for construction and operations are ISO 14687, ISO 14687–2:2012(EN) Part 2, SAE J2719 (2015) and Directive 2014/94/EU. An **initial general permit** is required as well as an **operational permit** and a **construction permit**. Application time is generally 8 months. Special case permits are required from the Directorate for Civil Protection for H_2 tanks above 0.4 m^3 or for tanks of greater than 5 tonnes. Applications for permits may need to be made to National Ministry of Local Government and Modernisation, the Climate and Pollution Agency and the Directorate for Civil Protection. In practice local municipalities may be able assist with all required permits. ADR/RID agreements (8.2.1, ADR/RID 2017, Norwegian version) apply to delivery, production, and operations. Pressure containers must meet ECE Standards No. 67 Revision 2, ECE Standards No. 110 Revision 12, or ECE Standards No. 115 or Standards (EC) No. 79/20094 in combination of Standards (EU) No. 406/20105, as relevant. Tier 4 high pressure (520 bar) possible if standards are agreed going forward. 3000 litres is maximum permitted storage at a dedicated HRS. For H_2 fuel cell HRS, **H_2 purity required is 99.999%**.
H_2 Vehicles	**Key legislation** for H_2 vehicles is ISO 14687–2, ISO 4687–2:2012 and SAE J2719_201511. There are no current restrictions on H_2 vehicles in Norway, with incentives including the use of bus lanes, exemption from VAT (25%), registration fees and toll charges. Type approval is completed by the Directorate of Public Roads, and vehicle registration by the Norwegian Public Roads Administration.

Table 5: summary of key Norwegian regulations

Sweden H_2 Data card	
H_2 Production	The **permit process** is the responsibility of the local municipality. Local environmental administration and emergency services are required to make assessments and give approval. A **building permit is required** for the handling of flammable goods. An additional building permit is also required **with local rescue service approval** for any H_2 electrolysis and storage locations below 1000 litres. Building permits are assessed within 10 weeks. For volumes greater than 1000 litres additional regional permission are required. H_2 electrolysis and storage below **50 tonnes requires a Seveso 1 report** to local rescue services, whilst **above 200 tonnes required a Seveso 2 report** and safety procedures to be in place. **Electrolysers** should be in approved industrial process areas only.
H_2 Transport & Distribution	The **key legislation** governing H_2 transport and distribution in Sweden is the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR). **Access limitations for transporting H_2** are the same as other flammable materials in Sweden with no special H_2 stipulations (ADR). Some tunnels may not be used during certain times (rush hour). A maximum **pressure limitation of 250 bar** is in place. For transportation, 'EX' classified vehicles are only to be used. And ADR-S certification must be met. **Permits are required**, and routing must be liaised with the National Traffic Administration for Route Planning. The Swedish Civil Contingency Agency oversees ADR and PED compliance.
HRS Construction & Operation	**Key legislation** for construction and operations are ISO 14687–2:2012. A **Handling of Dangerous goods permit** is required for operations and a building permit for construction. A **250 bar operational pressure** is normal. The applications process should take six months. **H_2 purity is required to be 99.97%**.
H2 Vehicles	**Key legislation** for H_2 vehicles is ISO_14687–2_2012, VVFS 2003:28 and VVFS 2003:29. There are no current restrictions on H_2 vehicles in Sweden, with incentives including a €6,000 incentive for low emission cars. Type approval is completed by the Swedish Transport Agency.

Table 6: Summary of key Swedish regulations

Denmark H_2 Data Card	
H_2 Production	**Permit** applications are the responsibility of the local municipality. If more than 5,000 kg of H_2 is to be produced, a Danish Emergency Management Agency (DEMA) Environmental **Permit** to handle and store inflammable gas is required from the Municipality Fire Brigade (as found in the Danish version of EU directive 2014/52/EU). If more than 10 litres of compressed H2 is stored, local municipality, building, fire, and environmental **permits** are required. Danish planning procedures include detailed use and development plan for the municipality. **If a municipality has not already planned for industrial gas** and or vehicle refuelling in the target area, **the Municipality plan will have to be changed first** before applying for any permits. Permitting process could take anywhere between 6 months and six years.
H_2 Transport & Distribution	The in addition to the usual EU wide ADR legislations, a **key legislation governing H2 transport and distribution** in Denmark is ISO_14687–2_2012. **Access limitations** are in place for the following tunnels, Limfjordstunnelen and Tårnbytunnelen tunnels are ADR 'A-class'. Øresundstunnelsen is B-class 23:00-06:00 and E-Class the rest of the time. **Quantities and pressure limits** are in line with ADR compliance, with 200 and 300 bar standard delivery. A **permit is required** to transport/distribute H_2 and is supplied by the Danish Transport, Construction and Housing Authority. **Route planning** must be in conjunction with local police authority and emergency department. ADR and PED compliance is required.
HRS Construction & Operation	**Key legislation** for construction and operations is ISO 14687–2:2012. An **Environmental (DEMA) permit is required** and design approval for parts not CE-marked. A Permit to handle and store inflammable gas is required for operations. Additionally, a building permit is required. The application and permitting process should take six months. **ADR compliance is required for operations,** with additional training modules. **200/300 bar is standard** for delivery with a **potential for 700**. Building and environmental permits are applied for via the Byg & Miljø (Building and Environment) agency **H_2 purity is required to be 99.999%.**
H_2 Vehicles	**Key legislation** for H_2 vehicles is ISO 14687–2:2012 and AE J2719_201511. H_2 vehicles are entitled to many of the same benefits and interventions as any other zero emission vehicle in Denmark. Incentives include free parking in some municipalities and tax exemption for zero emission vehicles. There are restrictions on H_2 vehicles in Denmark: FCEVs are not allowed to use bus lanes and are not entitled to discounts zero emission discounts in tunnels, bridges, or ferries. Type approval is completed by the Danish Road Safety Agency, and registration by SKAT motor registry offices.

Table 7: Summary of key Danish regulations

Netherlands H_2 Data Card	
H_2 Production	The **local municipality is responsible for most applications** under the Environmental Act - Omgevingswet. The **provincial authority** may be the permit granting body for **BRZO/Seveso III production amounts**. The BRZO plan applies the European Seveso III directive. A **land use plan** is required for large H2 production (special planning act) under the Environmental Act - Omgevingswet/Wet Algemene Bepalingen Omgevingsrecht. Legislation for H_2 fuel use and production differ depending on if H_2 is directly manufactured as a fuel, or if the H_2 is a by-product from another process that is then used as fuel. Only H2 that has been produced via the electrolysis of water (using electricity from renewable energy sources), or via steam reforming of biomethane, can be considered a renewable fuel. Waste H_2 processes would require local municipality authorisation to be classed as a zero emission fuel. ATEX is applicable. Approval of commissioning and of pressure-holding equipment is required. ATEX Specialists are required to complete inspections. Municipalities are to check inspectors have given licences to operate, and the fire brigade must be informed of activities and give approval.
H_2 Transport & Distribution	The **key legislation governing H_2 transport and distribution** in the Netherlands is ISO_14687–2_2012. **Access limitations** are in line with the ADR. **Quantities and pressure limits** are 200 bar and a maximum of 400 kg per truck in steel tubes. Up to 500 bar and 1100kg in carbon tubes with a GVW limited to 44 tonnes. 300 bar is the typical working pressure. A **permit is required** to transport/distribute H_2 and "CCVB" certificates are required for transporting Gasses and liquids. RDW Government road department issue the certificates. The Ministry of Infrastructure and Environment decide who has authority along a given route. **Route planning and permissions** are usually the responsibility of road owner (National, Provincial, local-authority or private company/individual). ADR and PED compliance is required.
HRS Construction & Operation	**Key legislation** for construction and operations is ISO 14687–2:2012 and ISO 11119-3. **No operational permits** are required, but an **application period of nine months** is to be expected. A building permit is required, called a De Wet Algemene Bepalingen Omgevingsrecht (Wabo) permit. This is applied for from the local authority for most sites or the provincial authority for industrial sites. A drivers licence for compressed/liquid gasses is required, with CCVB certification. 200 bar delivery is standard, with 500 bar possible but with limited technology availability. Bi-annual checks for ADR compliance must be completed. **H_2 purity is required to be 99.9995%**.
H_2 Vehicles	**Key legislation** for H_2 vehicles is ISO 14687–2, ISO DIS 19880–8, prEN 17124 with additional national limits for ammonia and sulphur limits (<1nmol/mol). There are no restrictions for H_2 vehicles in the Netherlands, with **incentives** including the Environmental investment allowance (MIA) and the Random amortization of environmental investments (Vamil). H2 cars are eligible for 36% MIA (purchase price reduction) and 75% Vamil (permissible capex-value write-off). Type approval is completed by the Road Safety Directorate, and H_2 vehicles must be registered with a 'W' starting letter.

Table 8: Summary of key Dutch regulations

Germany H_2 Data Card	
H_2 Production	The **building regulatory authorities grant building permits** with each state having its own authority. Land use plans are preparatory plans (Flächennutzungsplan) which are related to wider municipal plans. The land use plan (Bebauungsplan), is the defined building plan, use and construction rights. The **Bebauungsplan will permit H_2 production if it does not interfere with the Flächennutzungsplan for the area**. Only industrial and commercial regions may have H_2 production facilities. For **storing H_2 up to 3 tonnes**, the permitting procedure laid out in the Ordinance on Industrial Safety and Health applies. A building permit is required for pilot plants. The Building Standards of Nordrhein–Westfalen does not require a building permit for stationary vessels for gases with a net capacity up to 5 m^3. For **H_2 production of 5 tonnes or more**, a prevention of hazardous accidents plan is required. **For H_2 production of 50 tonnes or more**, a safety report detailing hazard prevention and security arrangement s is required. This must comply with Berufsgenossenschaften (trade association and employer liability) requirements. For **30 tonnes or less of onsite production and storage** construction and operation permit after completing the simplified permit application. For **greater than 30 tonnes**, public participation required before construction and operation permit granted. Environmental impact is also required
H_2 Transport & Distribution	The **key legislation** governing H_2 transport and distribution in Germany is ISO_14687–2_2012. **Access limitations** are in line with the ADR, with special instructions being the tunnel Alsterkrugchaussee in Hamburg has category E from 6 a.m. till 9 p.m. and C for the rest of the time. Tanked H_2 is permitted in category A tunnels, and cylinders in B & C. **For pressures**, the pressure vessel must have a safety factor of 3:1 burst pressure to nominal fill pressure. The maximum GVW is 40 tonnes. **H_2 transported under PED** is limited to 450 litres for cylinders and 3000 litres in tubes (this may increase for composite tubes as legislation develops). The Federal Ministry of Transport and Digital Infrastructure lists tunnels and restricted areas for ADR. National law is that the parking of motor vehicles with a maximum authorized mass exceeding 7.5 tonnes and trailers with a maximum authorized mass exceeding 2 tonnes within exclusively or generally residential areas is prohibited between 10 p.m. and 6 a.m. as well as on Sundays and public holidays. Specific local conditions and route planning is overseen by the State Transport Ministry. The transportation company must appoint a dangerous goods officer with a valid ADR-Card. Driver must have specific ADR training for the cargo carried. Industrial and Commercial Chambers (IHK) in each district issue certification.
HRS Construction & Operation	**Key legislation** for construction and operations is ISO 14687–2:2012 and O standard ISO/DIS 17519:2017(E). **No operational permits** are required, but an **application period of twelve months** is to be expected. A **building permit, construction and operations permit** is required. An ADR safety factor of three must be adhered to for storage equipment, and these must in line with the Pressure Equipment Directive. CE certification is required for H_2 cylinders of 1 m^3 or more. 400 litre maximum per cylinder and 3000 litre maximum for tubes. **H_2 purity is required to be 99.97%**.
H_2 Vehicles	**Key legislation** for H_2 vehicles is ISO 14687–2, ISO 14687–2:2012, SAE J2719_201511 and CMS 70. There are **restrictions on H_2 vehicles**, with underground parking being prohibited for H_2 vehicle at the request of garage owners. **Incentives include** reserved parking, reduced or no parking fees, exemptions from road access restrictions, 50% reduction for company car tax rates, up to €4,000 incentive. A requirement that 20% of fleets consists of zero emission vehicles (BEV, FCEV).

	Type approval is completed by the Federal Motor Transport Authority. Individual vehicle approval is completed by the regional Genehmigungsbehörde, Landesamt. And individual vehicle registration completed by Zulassungsbehörde für Kraftfahrzeuge.

Table 9: Summary of key German regulations

Belgium H_2 Data Card	
H_2 Production	There are three land-use plan levels in Flanders: Regional, provincial, and municipal. There are no exclusions for H_2, but the H_2 production must be compatible with other activities in each area. The local (municipal) Ruimtelijk Uitvoeringsplan plan may limit specific installations. All permit requests in Flanders must be submitted to the same digital "omgevingsloket" portal. Provincial authorities are responsible for all H_2 (class I) installation permits.
H_2 Transport & Distribution	The key legislation governing H_2 transport and distribution in Belgium is ISO_14687–2_2012. Access limitations are in line with the ADR, with seven class E tunnels two class D and one class C. No real quantity or pressure limits are declared, but container and vessel design limits must be adhered to. ADR certification and technical controls monitoring (once every six months in Flanders, yearly in the rest of Belgium). In Flanders, the Department Mobility and Public Works are **responsible for ADR route planning**. Note that Waloon and Brussels have different route planning authorities but fall outside the NSR. Periodic technical controls are required every six months in Flanders and Brussels, and once a year in Wallonia. ADR controls are completed once a year. Both are completed by a NOBO, accredited centres for vehicle inspection. Pressure equipment directives apply, ADR driver certification applies.
HRS Construction & Operation	**Key legislation** for construction and operations is ISO 14687–2:2012. **No operational permits** are required, but an **application period of five months** is to be expected. **An environmental class 1 permit** is required with the province responsible. ADR certification and technical controls monitoring occurs every six months in Flanders and yearly in the rest of Belgium. **H_2 purity is required to be 99.97%**.
H2 Vehicles	**Key legislation** for H_2 vehicles is ISO 4687–2:2012, ISO 14687–2:2012 and SAE. There are **restrictions on H_2 vehicles**, with underground parking being prohibited for H_2 vehicle at the request of garage owners. **Incentives include** the exemption of low emission vehicles from paying annual vehicle tax. **Type approval** is completed by three authorities depending on region. 1) the Flemish Department of Mobility and Public works, Section Policy for Mobility and Road Safety. 2) Public Service of Wallonia, Operational General Directorate of Waterways Mobility – Certification and Approval Department. And 3) Service for registration of Vehicles of the federal public service Mobility and Transport.

Table 10: Summary of key Belgian regulations

UK H_2 Data Card	
H_2 Production	The Town and Country Planning Act applies for all H_2 production facilities. Safety and safety hazard design and control of risks must be reported. Any H_2 production in Scotland is considered an industrial process regulated by Pollution Prevention and Control Legislations (PPC). Local Plan (Town & Country Planning Act) set by the local planning authority for an industrial activity and the plant H2 production must be deemed safe to operate; and a Local Authority Environmental Permit required. ATEX requirements may also apply to site operation, in which case the site will need inspection by the Health & Safety Executive and an operation must be run in accordance with Health & Safety Executive procedures. For **H_2 greater than 2 tonnes** hazardous substance controls are required, and a full risk assessment is needed for site. For **H_2 greater that 5 tonnes** COMAH legislation applies, and a Hazardous Substance Assessment is required.
H_2 Transport & Distribution	The **key legislation** governing H_2 transport and distribution in the UK is ISO_14687–2_2012. Access limitations are in line with the ADR, with nine tunnels having restrictions on flammable and explosive cargoes. Drivers must be trained to the standards of the UK HSE. Vehicles must meet “design, construction and use” standards, but no specific upper-pressure limit although Pressure System Safety Legislations adhere to pressures over 0.5 bar. Annual inspections are completed of vehicles. Vehicle certification agency approval is required to transport H2 (includes ADR certification) and Pressure Equipment Regulations apply. The normal range of working pressures are 350 or 700 bar. Pressure Equipment Regulation’s (Pressure equipment directives) for the design, manufacture, conformity, and assessment of equipment for transporting gasses. Approval and certification of vehicle chassis rests with the Driver & Vehicles Standards Agency (DVSA). No route planning authorisation is required other than respecting ADR tunnel classifications. However, the driver must be trained for the specific type of cargo with the transport company liable for driver training, “design construction and use” and ADR compliance. The UK Vehicle certification Agency ensures compliance annually.
HRS Construction & Operation	**Key legislation** for construction and operations is ISO 14687–2:2012. **Permission must be obtained to install and operate** a H_2 facility from the local authority. APEA “Blue Book” standards apply. An **application period of eight months** is to be expected. Pressure Equipment Regulations apply. The normal operating pressure is 350/700 bar. **H_2 purity is required to be 99.97%**.
H_2 Vehicles	**Key legislation** for H_2 vehicles is ISO 14687, ISO 4687–2:2012 and SAE J2719_201511. There are **no restrictions on H_2 vehicles** in the UK, although car park operators can specify limits. Restrictions do apply for H_2 buses and trucks. Applicable **incentives** include 0% corporate vehicle road tax, no car tax, and up to £3,000 plug in car grant. **Type approval** is completed by the Vehicle Certification Agency.

Table 11: Summary of key UK regulations

7 Lessons Learned

The HyTrEc2 Consortium has direct experience of HRS installation and the purchase and maintenance of H_2 vehicles. This section lists some of the lessons learned by HyTrEc2 consortium members during HRS and vehicle operation.

7.1 Aberdeen

ACHES HRS – Lessons learned (Operations 2018)

Theme	Comments
Nozzle	Ensure that all future vans and cars are compatible with the TK17 nozzle. 350 bar Kangoos and Transits had to be adjusted to fit.
Attendants	Ensure job descriptions for new/novel jobs are descriptive about all tasks and with a suitable pay grade for risks and responsibilities to prevent losing staff. Hired company to operate rather than employing attendants through ACC.
Testing	Ensure refuelling testing equipment is used for future stations as there has been a lack of cars available for adequate testing. A device can be used where the H_2 is released so driving of a car to get rid of H_2 is not necessary.
Tokheim	Ensure data stored in Tokheim system is not too much as exceeding data levels can stop the dispenser working.
Operator Contract	Ensure operator provides training to their staff on the use of fire extinguishing equipment - put this in the contract.
Operator Contract	State in the contract whether operator will be closed on public holidays.
Operator Contract	Put in the contract that operator will be responsible for sourcing and paying for consumables (nitrogen).
Operator Contract	Ensure operator will update drivers if the station is down.
Operator Contract	Put in the contract that the operator will be responsible for setting up Tokheim dispenser system, fobs and sending monthly reports to ACC.
Procuring Station	When procuring a station set it up so that the information on fuelling pressures and length of fuelling is easily collected (Within Tokheim instead of huge CSV files).
Nitrogen	Liquid nitrogen tank can go down to 0%. If it goes to 20% provider should be contacted. Combination padlock was installed to compound so provider can access the tank with no one on-site.
New vehicles fuelling	HRS need a remote software engineer and an engineer on-site to set up fuelling for new vehicles. They need as much notice as possible to plan for new vehicles.
Lighting timer	Lighting timer set to light dispenser and charging points during 8 am-6 pm during darkness hours.

7.2 Tromsø

The original plans for a hydrogen deployment project in northern Norway had considered adapting pre-existing BEV passenger vehicles to use hydrogen power trains. The time spent in contacting companies for retrofitting the EV and setting up a refuelling facility was useful as many lessons were learned. However, a significant change in approach was required: TromsØ disregarded their original plan to retrofit a BEV passenger vehicle. Instead, improved H_2 refuelling facilities (HRS) were prioritised. The cost of retrofitting an existing EV van/passenger vehicle was higher than buying an existing Hyundai/ Toyota FCEV. Directing budget at improved hydrogen infrastructure was identified as the best use of available funds and resources. HRS availability is the dominant factor in hydrogen transport technology deployment.

When considering the retrofit of hydrogen power trains to vehicles, the key issues identified were:

- Placement of equipment (Fuel cell, H_2 tanks, accessories) require space inside and outside the vehicle, which leads to reducing the available space for cargo and passengers.
- ICE and BEVs are not designed with suable air intakes for fuel cells. This dictates the implementation of a large air compressor. Increased compressor size increases noise, and parasitic energy demands on the fuel cell itself. Therefore, the overall efficiency of the retrofit FCEV is reduced significantly.
- Technical problems were faced with DC-AC converter, which is not commercially available to match the fuel cell and the Synchronous motor on board the Nissan Van. The converter had to be designed on-demand but was not able to deliver the same power output of the fuel cell (resulting in a drop in fuel cell power-output and reduced efficiency).
- Technical problems were faced with the reconditioned fuel cells (the exact technical issue was undefined: reconditioned fuel cell units were returned to the fuel cell manufacturers in a sealed state to comply with supplier warranty and intellectual property rights).
- Safety issues with the retrofit, the H_2 tanks and the whole system: The passenger compartment must be sealed away from any likely H_2 leak. Passenger compartment sealing created further complications and further reduces the available space in the vehicle.

7.3 Cenex

Direct measurement of dispensed H_2 per vehicle needs to be automated. Reliance on driver records of fuel use is not advised:

- Multi-fuel systems (range extended EVs or dual fuel H_2/diesel) are extremely difficult to track reliably.
- Data analysis is skewed by under-reported power-train issues. For example. If the HRS goes offline, range-extended vehicles rely on battery power only, and dual fuel power train vehicles rely on diesel only. The inoperability of HRS for even a few hours can significantly skew results due to changes in driver behaviour.

Several key issues in motoring fleet use were encountered during the project:

- Vehicle data was gained by tracking devices. A key issue was the removal of tracking devices from vehicles without Cenex being informed. Software systems were updated to automate notification of prolonged (24 hours) loss of signal.
- In this study, data capture was from a variety of vehicles. Tracking devices were swapped between vehicles regularly. Updated tracker identification and vehicle assignment protocols had to be developed.

- Dedicated in-house data servers were set up to ensure data integrity, data security and automated reporting procedures:
  - Data loss from 3rd party host companies became a significant issue as the project evolved, and the number of vehicles increased
  - 3rd party data security became a significant issue as the project evolved, and GDPR legislation came into force.
  - Creating automated reporting and alert procedures using 3rd party host companies proved extremely complex.

8 Summary

The HyTrEc2 project brings together organisations from the eight North Sea region countries, with an interest or experience in hydrogen (H_2). The HyTrEc2 consortium collaborate on the development of strategy and initiatives across the NSR and support the further use of H_2 internal combustion engines and fuel cell electric vehicles (FCEVs) in the NSR. The HyTrEc2 project is part of the Interreg VB North Sea Region Programme, and the European Regional Development Fund. Sustainable transport solutions (such as H_2) will play a key role in achieving EU energy and climate change targets. HyTrEc2 seeks to foster an FCEV market and develop the NSR as a centre for excellence for H_2 and fuel cells. HyTrEc2 aims to reduce the cost of H_2, H_2-powered vehicles, and reduce CO_2 emissions by;

- Improving the operational efficiency of a wide range of vehicles such as vans, large trucks and refuse collection vehicles.
- Improving the supply chain and training so that the NSR becomes a centre of excellence for H_2 transport and helps create a competitive environment.
- Developing innovative methods for the production, storage, and distribution of green H_2.
- Ensuring that the NSR is the dominant region in the EU in terms of H_2 transport. The project will complement national programmes and facilitates joint NSR approaches and common standards.

This report considerers the variation of H_2 legislations, codes, and standards (RCS) that affect issues such as safety, fuelling and validation of H2 vehicles across the NSR. Note that this document is for guidance only. All readers should use this document to direct themselves to the relevant legislation that impacts their day-to-day operations when considering the transition to H2 as a fuel for transportation. **H2 is expected to become an important energy vector for transport, heat, and power across the NSR, as well as continuing in its traditional role as a critical chemical feedstock.** To comply with international and national global warming commitments, decarbonisation by utilising zero-emission H2 must begin with technologies that are available today.

All NSR countries have similar commitments to reduce emissions from transport, heat, and power generation. Each presents different strategic and policy drivers to ensure that change happens, depending on the country’s specific circumstances. A brief summary of each nations energy policy, storage and H2 production capability was discussed in section 4.

Vehicle manufacturers and converters need approval before putting vehicles on public roads. Certifying that vehicles meet relevant legislations and standards is a crucial part of their deployment on the road and commercial roll out from a safety perspective for both the use of the vehicle and the interoperability of vehicles with refuelling stations. The European Community Whole Vehicle Type Approval (ECWVTA) provides a mechanism for ensuring that vehicles meet relevant environmental, safety and security standards. Approval and certification of H2 vehicles is a nationally devolved activity. All EU countries have their procedures and departments for providing approval for either small numbers of vehicles or type-approval for a larger number of vehicles. The general principles covering the approval of vehicles for use on the roads in the NSR are closely related to EU legislation and directives. Theoretically, any EU nation that provides type-approval to a vehicle should be valid in all EU nations. However, in practice, it is recognised that the German automotive sector type-approval process is the most stringent in conforming to EU legislations and directives. Therefore, any proposed H2 vehicle, or vehicle for transporting H2 by road between NSR countries, would be well advised to seek road worthiness approval through a German test house. Section 5.2 discusses this in much greater depth.

Section 5.3 considers the production and storage of H_2. This is of relevance for many H_2 vehicle demonstration trials. For many H_2 vehicle trials, dedicated H_2 refuelling systems will also have to be installed. The H_2 must either be generated or delivered to the HRS site and then stored in sufficient quantities to complete the hydrogen demonstration project. The storage and production of H_2 are affected by some of the same legislation. The SEVESO Directive (above five tonnes of H_2), the ATEX (above one tonne of H_2) and Pressure Equipment Directives apply. Together these impose obligations on operators and manufacturers of equipment. The SEA and EIA Directives would also apply, subject to national conditions (for example, above 5 tonnes of H_2 storage.)

If H_2 is not generated on site for immediate use in vehicles, it is likely that legislation governing the transport and distribution of H_2 (section 5.4) will apply. There are multiple agreements concerning the International Carriage of Dangerous by road, rail, water, or air. classification, labelling and packaging of substances (CLP) and Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) legislation applies to the transport of H_2. if H_2 is transported as a pressurised fluid, transport of pressurised equipment directives also applies.

To create NSR H_2 guidance, an overarching summary of EU legislation has been presented. Additional national, regional, or local legislation has also been identified and is presented in table format. The increased technical requirements summary for the NSR, based on **the most stringent technical requirements for hydrogen transport technologies was presented in section 5.6, Table 3.** Taken together, the EU, national, regional, and local standards, directives, legislation and permitting procedures combine to create an NSR guidance on H_2 production, storage, distribution and use for transport purposes. Having developed an understanding of the NSR baseline (EU) legislation and standards, national limits should also be complied with for those vehicles operating on H_2 or delivering H_2 supplies in and around individual countries in the North Sea Region.

In addition to the national variations to baseline EU legislation, **summary data cards were presented in section 6 for each of the NSR nations**. The data cards are a 'quick reference' guide to assist companies with operations NSR regions seeking to develop H_2 transport solutions. A road-based compressed gas H_2 transporter must comply with the following limits:

- Comply with all EU legislations and directives on the transport of dangerous goods, pressurised equipment directives and, if relevant ATEX or SEVESO regulation.
- Gross vehicle weight for road transport must not exceed 40,000 kg.
- All pressurised safety equipment must be designed with safety factors greater than three.
- The maximum permissible mass of compressed gas H2 that can be transported is 200 kg per cylinder.
- Compressed gas H_2 cannot be transported at more than 200 bar pressure.
- The maximum equivalent water volume of road transport storage containers is.
    - 450 litres for cylinders.
    - 3,000 litres for tanks or 'tubes'

More broadly, EU wide legislation is the backbone of H_2 legislation and standards across the NSR. Each nation in the NSR may have additional permitting and legislations on top of the baseline EU framework; but all NSR nations apply EU standards at a minimum. Organisations considering the transition to H_2 technologies need to aware of their legal and safety requirements at the start of their transition to a H_2 transport solution. The first step in this process is to quantify the largest likely amount of H_2 stored or generated in the life of the project. The next consideration is the likely storage pressure of the H_2. Lastly, the sites and locations where the H_2 will be present (either as static storage or during its transport between sites) must be identified. The project manager can then review the legislative framework and quickly identify which, if any, legislation may apply. **Many of the legislation and standards identified in this report will not apply to smaller H_2 projects, particularly fleets that are users of small numbers of H_2 vehicles rather than producers of H_2**. As a very broad generalisation, **for H_2 projects based in industrial or commercial zones, the legislative requirements become more stringent when:**

- **200 kg (or more) per day H_2 production & transport is required; or**
- **1,000 kg (or more) of H_2 storage is required**.

Having explored the legislative framework on the deployment of H_2 transport technologies in the NSR, a direct 'lessons learned' report from each of the Hytrec2 partners was presented in section 7. Some of the key knowledge to gained from the experience of the Hytrec2 partnerships were:

- The availability of HRS should be the priority, as it is not sustainable to have a vehicle without having a sustainable H_2 supply and refuelling ability.
- Technical specifications for fuelling nozzles differ between HGVs, buses, and passenger cars.
  - Therefore, great care must be taken to ensure operational suitability for all vehicles
- Use on site combination locks for secure facilities, not keys is critical for emergency response
- New models of vehicles will need to programmed into the refuelling software. Allow budget and staff to support this activity as new fuel cell vehicles are released
- Dedicated in-house data servers are recommended to ensure data integrity, data security and automated reporting procedures; "cloud" based data services prone to data loss, and automated data capture and processing is difficult to integrate with 3rd party cloud-based systems. GDPR requirements make in house data servers more attractive when considering data security, and compliance with GDPR principles.

The legislative requirements for H_2 production, storage distribution and use scales with the amount of H2 being considered. There are different requirements depending on the mass of H_2. Key breakpoints in the legislative steps for H_2 occur at the following levels:

Mass of stored hydrogen	NSR National or European legal requirements
40 kg	De Minimis limit for reporting stored hydrogen in the UK
100 kg	H_2 is now classified as a chemical product and subject to Classification, Labelling and Packaging of Substances and Mixtures Directive 1272/2008 The upper limit hydrogen production rate per 24 hours outside of industrial and chemical zones
200 kg	upper limit of a single steel cylinder of compressed H2 in Germany and Sweden. The upper limit of H_2 storage outside of commercial or industrial zones.
333 kg	For liquid H2 - ADR section 1.1.3.6 for flammable gases (type 2.1) limit of full compliance (values below this need only adhere to 'ADR light' and local legislations.). 333 kg of liquid H2 in a tank or 'tube' is the typical upper limit for class D & E tunnels.
450 kg	ADR and TPED limits for a single steel cylinder of compressed H_2
1,000 kg	Practical upper limit for steel-walled cylinder compressed gas distribution of H_2 due to; the technical limits of steel-walled containers, the standards on transport of compressed flammable gasses, and the design and approval of vehicles legislation.
2,000 kg	UK's lower limit of Planning Hazardous Substances regime
3,000 kg	ADR and TPED limits for a steel single tanker of liquid H_2. Note that additional permits required in Germany (Federal Emission Control Act)
3,500 kg	Practical upper limit for composite walled compressed gas cylinder distribution of H_2 due to; the technical limits of composite walled containers, the standards on the transport of compressed flammable gasses, and the design and approval of vehicles legislation.
5,000 kg	EU Wide lower limit tier 1 of the SEVESO threshold Danish upper limit before local permits to store H2 are required.

Mass of stored hydrogen	NSR National or European legal requirements
	UK's lower limit of the Control of Major Accident Hazards (COMAH) 2015 legislations thresholds
30,000 kg	German threshold for public consultation and permits for operation and use
50,000 kg	Sweden's the lower limit for stored H_2 for local reporting policies
200,000 kg	Sweden's upper limit for tier 1 stored H_2 for SEVESO reporting policies

Table 12: Summary of hydrogen mass-based standards limits

The unified FCEV guide for all NSR countries; In summary, each NSR member state has been assessed and summarised through a "RAG analysis" of the legislative framework in each NSR country.

RAG Colour	H_2 production	Stationary Storage	Transport & Distribution	H_2 as Fuel and refuelling infrastructure	FCEV and H_2 transport type-approval
Red	High purity limits =>99.99. Or industrial site production only for =>100 kg/day.	Industrial site storage only for =>200 kg.	Maximum pressure of 200 bar and 200 kg for compressed gas transportation.	Industrial/commercial sites only.	No local facilities for vehicle type-approval.
Amber	medium purity limits =>99.97 to =>99.99. Or industrial site production only for =>200 kg/day.	Industrial site storage only for =>2,000kg.	Maximum pressure of 500 bar and 300 kg for compressed gas transportation.	Residential filling permitted but not at existing Filling station forecourts.	EU compliant type-approval.
Green	lowest purity limits <= 99.97. Or industrial site production only for =>500 kg/day.	Industrial site storage only for =>5,000 kg.	Maximum pressure of 750 bar and 500 kg for compressed gas transportation.	Filling station forecourt pumps.	Rigorous application of EU standards for type-approval.

Table 13: Red-Amber-Green (RAG) analysis definitions table

Country	H2 production and (gas purity for PEMFC vehicles)	Stationary Storage	Transport & Distribution	H2 as Fuel and refuelling infrastructure	FCEV and H2 transport type-approval
Norway	No mass limits, (99.999)		520 bar max		
Denmark	(99.97)		No defined limit		
Sweden	(99.97)		national 250 bar max		
Belgium	Excludes on site HRS	Excludes on-site HRS	No defined limit - local 300 bar max	Onsite H2 production permitted	
Netherlands	(99.97)		500 bar max		
Germany	(99.97)		No defined limit - safety factor greater than 3		
UK	(99.97)		No defined limit - practical limit ~1,000 kg	"Under canopy" installation guidance in place	

Table 14: RAG analysis of hydrogen transport legislation in NSR countries

Lowering your emissions
through innovation in transport
and energy infrastructure

Transport

Energy Infrastructure

Knowledge & Enterprise

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