New Bus ReFuelling for European Hydrogen Bus Depots

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Review of regulations codes and standards with respect to hydrogen bus scale fuelling, with a focus on highlighting best practices and recommendations on RCS changes required

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0. About the NewBusFuel project

Hydrogen buses are recognised as one of very few routes to the full decarbonisation of public transport in cities. This project aims to fill a major gap in the existing knowledge base around the refuelling of hydrogen at a bus depot scale. Existing hydrogen refuelling stations (HRS) have been designed and operated with maximum fuelling capacities in the 100s of kg/day. For hydrogen to be a viable fuel for bus operators in the medium term, solutions are required which can provide fuel for 100s of buses, which implies fuelling requirements of 1,500 kg/day and above. Providing fuel at this scale creates new challenges which have only been tackled in the most theoretical fashion by the hydrogen industry. There is a considerable knowledge gap around the designs, processes and safety implications of providing hydrogen refuelling on this scale. A large and truly pan-European consortium has assembled to develop solutions to these challenges. The consortium will carry out engineering studies for 13 different large scale hydrogen fuelling station designs at 12 different sites.

There are four main project objectives, which can be prioritised in the order below:

- Produce 13 engineering studies which define the optimal designs, hydrogen supply routes, commercial/ownership arrangements and the practicalities involved in refuelling very high volumes of hydrogen at a variety of busy bus depots across Europe.
- Prepare a range of publically accessible, design guideline reports based on analysis across the engineering studies which are carried out. The diversity and the number of studies carried out will allow a comprehensive engineering data set to be assembled. A comprehensive program of evaluation of the engineering dataset will allow the production of valuable learning for the European bus sector.
- Kick start the large scale bus deployment projects which are required for the next stage of the commercialisation process. The study sites have been selected to be located in Europe's most proactive hydrogen bus deployment regions. In each region, the study will enable the operators and their industrial partners to make steps towards their next wave of hydrogen bus deployment.
- Disseminate the results to a wider audience in order to ensure that the challenge of hydrogen fuelling for buses is not seen as a credible reason to delay engagement with the technology.

1. Introduction

Regulations, codes and standards (RCS) are implemented to ensure technologies are designed and constructed with adequate safety, quality and efficiency considerations. Robust RCS are essential to the success of any mass market technology as they give certainty and assurance to all stakeholders involved and thereby help to de-risk investment (e.g. by minimising risk for financing organisations).

Hydrogen transport is an emerging sector, which means the RCS for hydrogen refuelling infrastructure are not as consistent or exhaustive as for other, more developed transportation sectors (e.g. diesel or methane). Regulators and governments have significantly varied experience with hydrogen transport and refuelling infrastructure and have inconsistent interpretations of existing RCS. Furthermore, many countries have hydrogen-related RCS that are designed for industrial gas handling rather than refuelling infrastructure and therefore needs to be revisited.

In the last 10 years, numerous hydrogen refuelling stations have been deployed in European cities for pre-commercial demonstration activities including public infrastructure for passenger vehicles and light commercial vehicles, as well as private infrastructure for fuel cell bus and fork lift fleets. For buses, refuelling stations have been deployed both in busy bus depots and on dedicated sites outside depots. In 2015, Linde/BOC commissioned the largest hydrogen refuelling station in Europe capable of dispensing 300 kg-H_2/day for Aberdeen's fuel cell bus fleet. These installations demonstrate that it is possible to install hydrogen stations with today's RCS albeit with widely varying interpretations across Europe.

Despite these early successes, RCS issues become increasingly relevant for large-scale refuelling solutions (1,000-2,000 kg-H_2/day), because the potential safety impacts become more significant as the amount of energy stored increases. For example, hydrogen fuelling sites can move into industrial site safety classifications, with associated restrictions and also significant bureaucracy. As the sector develops towards commercialisation and the associated refuelling sites become larger, the RCS problems have the potential to become more acute. As a result, a key objective of the NewBusFuel project was to identify significant RCS barriers and challenges for large-scale refuelling.

This report summaries RCS issues encountered during the development of the 13 engineering studies for large hydrogen refuelling stations and describes recommendations to improve RCS where relevant.

2. Approach

An RCS working group was established at the start of the NewBusFuel project to share RCS lessons learned from individual studies and potential solutions to issues identified. RCS related issues affecting large-scale refuelling will differ across different European Member States therefore the working group included all bus operators and HRS developers from the consortium. Lessons learned from past projects (CHIC – D4.3 & D3.7) were also a key input into this working group.

At the start of the project, the working group established the main regulatory issues to be considered during the engineering studies, including:

- Restrictions on the storage of high volumes of hydrogen
- Restrictions on the movement of hydrogen
- Safety exclusion distances from various nearby activities
- Indoor/outdoor hazardous gas handling regulations
- Time- or geography-specific noise and air quality limits
- Heavy goods vehicle movement regulations
- Anti-terrorism and security restrictions, etc.

From this, the working group agreed on four questions to be answered by each study team:

1. What are the applicable regulations, codes and standards?
2. What hurdles were encountered for specific designs?
3. What options exist for changing existing regulations?
4. What cost implications arose from particular regulations?

All 13 study teams provided responses to the four questions and for each issue encountered. Furthermore, where significant additional complexity is added to designs or the deployment of large depots is made infeasible due to RCS issues in specific locations, study leaders were asked to provide recommendations to alter these barriers through adopting best practice RCS found in Member States that do not pose such severe barriers to deployment.

The NewBusFuel basic engineering studies have been useful for industry partners in determining the most important RCS issues that might delay or add cost to an HRS installation. However, the basic engineering studies only enabled certain aspects of the HRS design to be understood from an RCS perspective. Detailed engineering analyses (e.g. quantitative risk assessment, vent dispersion analysis, ATEX zoning[1]) are needed to identify certain complex issues but are beyond the scope of the NewBusFuel project. As a result, the assessment of RCS issues encountered and recommendations for best practice will aim to address the most crucial RCS issues that industry partners encountered, but should not be considered a fully exhaustive assessment.

[1] ATEX refers to two EU directives (99/92/EC and 94/9/EC) for controlling explosive atmospheres

3. Assessment

3.1 General assessment

All HRS developers in the NewBusFuel consortium (Linde, Air Products, ITM Power, McPhy, Hydrogenics, H2 Logic, HYOP, Abengoa Innovación, Vattenfall) have experience of designing and deploying hydrogen refuelling stations in Europe and therefore are familiar with the RCS environment. Building on prior knowledge and experience, the HRS developers were able to identify the main RCS issues relevant to large HRS designs.

The 13 study teams provided varied responses to the RCS questions (see Annex). A number of partners provided extensive feedback and suggested recommendations where as other partners commented that no RCS issues were encountered during their engineering study suggesting different prioritisation of the various aspects of a basic engineering study. Furthermore, in Hamburg, an expert safety survey was conducted by INUBREX prior to the engineering studies.

Six main RCS issues were identified to have caused difficulties during the engineering studies (see Table 1). Restrictions for total on-site hydrogen storage and disharmonies between local and international RCS were the most common issues identified.

Table 1 – Six main RCS issues identified from the 13 NewBusFuel engineering studies

RCS issue	Description
Storage capacity limitations	▪ Existing local RCS for on-site hydrogen storage relate to traditional industrial gas handling and have not been updated to consider hydrogen refuelling for transport. ▪ Many examples were recorded of national RCS prohibiting (logistically and economically) the preferred capacity of on-site storage which is required to meet bus operators' demand requirements. ▪ Generally the issue here relates to the higher quantities of storage altering the safety classification of the site, which in turn creates additional cost and/or restrictions on what can be installed. ▪ *E.g. UK law for hydrogen storage (COMAH) relates to facilities with >5 tonnes of on-site hydrogen storage and would require longer, more costly and complex permitting procedures.*
Disharmony between local and international RCS	▪ Local interpretation of international RCS can lead to overly severe restrictions being imposed which can prevent industry from applying standardised solutions, thereby significantly increasing HRS capital and operating costs. ▪ *E.g. Italian law is stricter than European law for HRS installations: the law*

	states the required safety distances around all components based on the amount of hydrogen and/or pressure level. For the quantities and pressures in the NewBusFuel project, the Bolzano study required distances up to 30m which would not be feasible for an urban setting. The law allows reduced distances steel reinforced concrete walls are built around the components resulting in significant additional cost.
Safety distance requirements	▪ Safety distances are the primary factor governing total HRS footprint. ▪ Many examples were recorded of national RCS requiring excessive safety distances that are not consistent with quantitative risk assessments and safety standards in other countries, thereby unnecessarily increasing station footprint and cost. ▪ *E.g. Riga's "law of safety distances" is stricter than the ISO standard. Riga law states that an area with a 25m radius must be kept clear around the HRS, and there must be at least 50m between the HRS fencing and any residential or industrial buildings.*
General planning authority issues	▪ Local planning authorities with little experience of assessing applications to build an HRS take considerable time to review applications and can involve multiple iterations. ▪ Can detrimentally impact the HRS installation timeline and the risk of this delay can mean that creating a business case can become challenging.
Unclear electricity tax exemption	▪ Electricity costs are made up many different components (wholesale price, taxes, levies, distribution and transmission costs, utility margin). ▪ Minimising electricity price is essential to the business case for operating an electrolyser, therefore understanding levy/tax exemption is important but currently not made clear by regulators in most countries. ▪ *E.g. German electricity prices include a 40% tax to pay for decarbonising the electricity grid. Industry feel that electricity for electrolytic hydrogen production should be exempt from this tax but there is no certainty from regulators.*
Absence of bus refuelling protocol	▪ Refuelling protocols for passenger vehicles have been developed and enable HRS developers to standardise equipment designs. ▪ Currently only a 'guideline' exists for bus refuelling which leaves considerable uncertainty. ▪ *E.g. HRS developers without significant prior bus refuelling experience will need to develop their own refuelling protocols for the dispenser(s) which could negatively impact procurement tender responses from new entrants to the HRS market.*

An overview of the RCS issues experienced during each study is shown in Table 2. A number of issues were experienced by multiple studies (e.g. storage restrictions or safety distance requirements) and some issues were unique to particular studies (e.g. unclear tax exemptions for electricity prices).

Table 2 – RCS issues encountered during the 13 NewBusFuel engineering studies

		Storage capacity limitations	Local and international RCS disharmony	Safety distance requirements	General planning authority issues	Unclear electricity tax exemption	Absence of bus refuelling protocol
1	Aberdeen	Y	N	N	Y	N	N
2	Birmingham	Y	N	N	Y	N	Y
3	Bolzano	N	Y	Y	N	N	N
4	De Lijn	N	Y	Y	N	N	N
5	Hamburg 1	N	N	N	N	N	N
6	Hamburg 2	N	N	N	N	N	N
7	London	Y	N	N	N	N	N
8	Madrid	N	Y	N	Y	N	N
9	Oslo/Akershus	Y	N	N	N	N	N
10	Potsdam	Y	N	N	N	N	N
11	Riga	N	Y	Y	N	N	N
12	Stuttgart	Y	N	N	N	Y	N
13	Wuppertal	N	N	N	N	N	N
	TOTAL ("Y")	6	4	3	3	1	1

3.2 Cost assessment

Three study teams from different countries provided estimates for the additional costs of adhering to a particular RCS (see Figure 1).

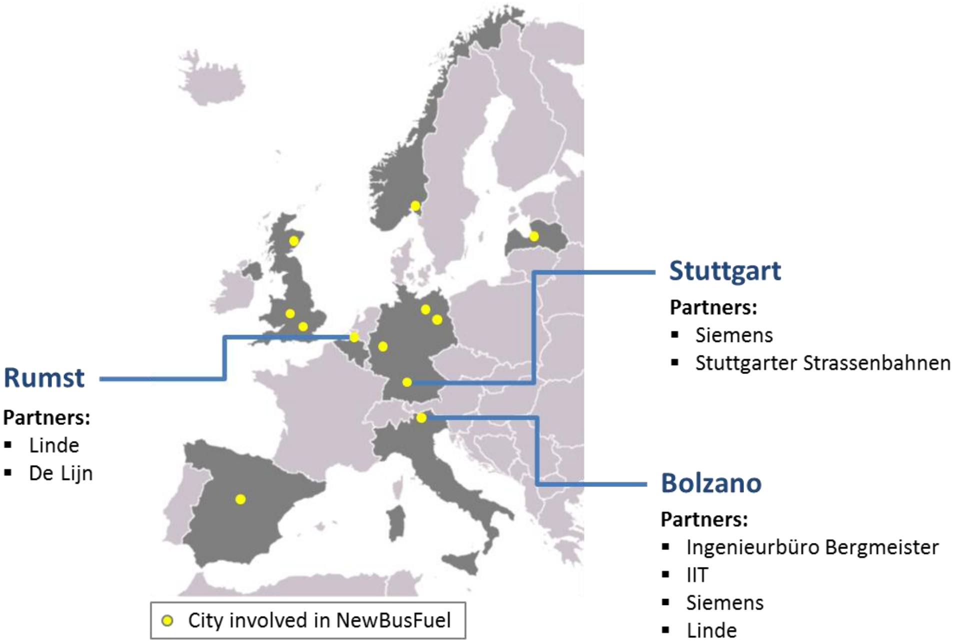

Figure 1 – Cities that required additional project costs to comply with local RCS

Rumst (Belgium): Disharmony between Belgian and international RCS resulted in higher, non-standard safety distances between equipment required for the HRS design. Linde estimated that additional separation distances between the pump container and storage tanks could result in an additional €0.1-€0.3 million of capital costs.

Stuttgart (Germany): Regulations have not made a clear statement about whether electricity purchased for electrolytic hydrogen production is exempt from the EEG fee which represents 40% of the total electricity cost in Germany. Depending on hydrogen production volume and electricity cost, the EEG fee could add up to €3/kg to the hydrogen price.

Bolzano (Italy): Disharmony between Italian and international RCS for safety distances required the HRS design to include dedicated buildings to house compression and storage equipment due to the limited space at the chosen HRS site. Construction of new buildings increased the HRS capital costs by an additional €0.5 million.

4. Recommendations

Develop a European HRS standard to harmonise local standards and assist planning authorities

ISO standards are based on feedback from the international community often making them very generic and are therefore considered as a minimum requirement. The absence of a European HRS standard (building on the existing ISO standard) required special planning permits to be sought for stations, often requiring considerable resource and multiple iterations with local authorities adding significant time to projects. An officially recognised harmonisation of European RCS will speed up the planning process.

Develop a bus refuelling protocol in accordance with protocols for passenger vehicles

The refuelling protocol for fuel cell passenger vehicles at 700 bar (SAE J2601) was developed from extensive analysis of all feasible permutations that might occur at a refuelling station (ambient temperature, quantity of hydrogen in tank, etc.) resulting in a complex series of protocols that must be programmed into the IT systems of an HRS. Currently, the refuelling protocol for buses at 350 bar is only a short addendum to the standard for passenger cars therefore experienced HRS developers have programmed their own protocols in consultation with tank suppliers. 350 bar refuelling is less technically demanding (no pre-cooling is required and 350 bar tanks are more robust) but the absence of a formal bus refuelling protocol is a challenge for less experienced HRS developers. Regulators should work with industry to develop a bus refuelling protocol based on industry's experience to-date to provide new entrants and small manufacturers with useful information and boundaries to comply with.

Allow HRS developers to use internal safety distance codes to expedite equipment standardisation

Inconsistent safety distance regulations require HRS developers to develop location-specific solutions for each customer incurring high non-recurring engineering (NRE) costs for new HRS designs. Introduction of a general term to relevant codes to allow approved HRS developers to implement their own risk assessment and associated safety distances would promote standardisation.

Introduce European standard for hydrogen pipelines

Pipeline regulations for compressed gases relate only to methane and to a maximum pressure of 250 bar. The absence of hydrogen pipeline regulations necessitated a special permit to be granted at the Belgium installation. A European standard describing how hydrogen pipelines should be designed would give certainty to project developers and reduce station lead time.

Update existing hydrogen-related RCS to reflect hydrogen transport applications and in particular the urban context

Many existing RCS for quantities of on-site hydrogen storage and safety distances were originally developed for traditional industrial gas handling and have not been updated to reflect the use of hydrogen as a transport fuel, advances in tank design and associated refuelling technology advancements. New work is require to allow regulators to revisit the industrial RCS surrounding bulk hydrogen storage when applied in a refuelling and bus depot context. Clearly this work needs to be carried out by relevant regulators in close collaboration with industry.

Schedule regular reviews of HRS RCS as sector matures

Many hydrogen refuelling technologies are still being improved for example, to establish accurate hydrogen metering, to allow new low pressure storage, novel compressors or to optimise electrolyser efficiencies. HRS configurations are likely to change in future as stations increase in size and technologies mature. Regulators should regularly consult HRS developers to review existing HRS RCS as technologies mature.

Conduct more detailed engineering assessment prior to project implementation

The NewBusFuel basic engineering studies enabled major RCS issues to be identified but further issues are likely to arise from more detailed assessments.

Where possible, European and national regulation could allow well engineered and analysed solutions to be proposed on a bespoke basis, as a stop-gap before the existing RCS are revised based on new data.

5. References

[CHIC – D4.3] Report collecting experience from the Phase 0 and Phase 1 cities with respect to certification of the buses and H2 refuelling infrastructure (April 2013)

[CHIC – D3.7] Experiences with the implementation of infrastructures for hydrogen refuelling and lessons for future installations (September 2014)

CHIC reports can be downloaded here: http://chic-project.eu/info-centre/publications

NewBusFuel reports can be downloaded here: http://newbusfuel.eu/publications/

6. Annex

Questionnaire responses from study teams

	Q1	Q2	Q3	Q4
	Q1. Applicable regulations, codes and Standards	Q2. Encountered hurdles for specific designs - Please give a summary of RCS-related issues encountered and solutions deployed per country. - If significant additional complexity is added to designs or the deployment of	Q3. Options for changing regulations - Please provide a description of areas where regulations have unnecessarily hindered the design or would hinder construction or other works (particularly where there would be merit in changing these regulations). Where changes to	Q4. Cost of regulations - Where regulations which you feel are unhelpful have been identified in the design, is it possible to provide a budget estimate of the cost of complying with the regulation (this will help making the case for a change in the
Aberdeen	- N/a	- Due to large amounts of hydrogen stored on site it is likely that Control of Major Accident Hazards Regulations (COMAH) may apply and thus lead to a longer/stricter/more costly permitting procedure. - Local authority planning department was consulted and indicated that the filling station is likely to be approved however, the site lies within a zone of a major hazard site (reasons for this are now inactive though) which requires consultation with the Health Safety Executive and due to possible impact on surrounding road network, the council's roads management team.	- N/a	- N/a
Birmingham	- See original spreadsheet for full list of Directives and Standards used.	- The biggest hurdle is the lack of a published refuelling protocol for buses. - It is understood that there are additional land planning consents required for installations which store >2 tonnes of hydrogen on site. - COMMAH and associated Health & Safety Executive assessments would be costly to have > 5 tonnes of hydrogen storage on-site. This is avoided in the Birmingham study by design. - Currently, there is uncertainty over the maximum allowable electrolyser pressure that the HSE will allow without removing the ability to restrict Zone 2 to Zone 2 of Negligible Extent by use of forced ventilation. - In future, it may be desirable to increase electrolyser operating pressure to reduce cost in other areas of the system.	- No major complaints	- None easily identifiable
Bolzano	- Extensive list of codes related to the project were provided including standards and laws for civil works, safety and fire prevention as well as technology related standards. - See original spreadsheet for full list of RCS.	- production/compression/storage: the Italian government regulates HRS construction and H2 production in a specific law (D.M 31/08/2006). The law is not aligned to European regulations and stricter compared to the standards used to build stations in the surrounding states. The law defines precisely the safety distances around the components depending on the amount of hydrogen and/or pressure level. For the quantities and pressures in the NewBusFuel project the distances up to 30 meters are asked which is hardly applicable in an urban area. For this reason the law offers a possibility to reduce the distances if walls of steel reinforced concrete are racked up all around the components. In either way the regulation causes higher cost for investment and maintenance. - Pipeline: there are no specific laws for hydrogen pipelines available in Italy. Rgulations related to pipes for methane distribution are limited for pressures up to 250 bar. For this reason the project had to be approved by the authorities and a special permit had to be granted A clear, European standard with technical instruction how such pipelines should be designed would avoid doubts and speed up projecting.	- Finding and defining a unique standard in Europe for hydrogen infrastructures offers various advantages. It facilitates the design of the stations, speeds up the design and construction of stations and, due to the higher numbers of units, costs decrease. - Furthermore the alignment of Italian safety distances has a positive impact on footprint and avoids part of the civil works, too. - Overall a common standard reduces costs and increases attractiveness for investments. A unification of the standards in Europe is therefore highly recommendable.	- In the current project the buildings for the compressors and the medium pressure are not necessary from a technical point of view and where only foreseen to fulfil the regulatory needs. This causes additional investments of more than 500.000 Euros and about 30.000 of annual expenses for maintenance. - Note: The low pressure storages vessels are about 18 meters high and have a diameter of about 3 meters. Strictly following the mentioned law would mean to encased also these components with concrete walls. Realizing so would cause complex civil works and therefore even higher costs. Further also the from an esthetical point of view it would be a massive intervention. It therefore was already agreed with the local safety agency that it would not be necessary and that a special permit to avoid the housing of the storage will be given.
De Lijn	- ISO/TS 20100:2008 --> 19880-1:2016: GH2 fuelling stations, General requirements - ISO 14687:2012 --> 19880-8:2016: GH2 fueling stations, Hydrogen quality control - Fill Instructionsfor 350 bar Hydrogen Systems and Cylinders according to Regulation (EC) 79/2009 - VLAREM II : Order of the Flemish Government of 1 June 1995 concerning General and Sectoral provisions relating to Environmental Safety	- Article 5.17.3.2.3 (Layout of the storage sites in VLAREM II). This article may require high/non-standard safety distances, which could require to change the station design. - A solution could be a discussion with authorities and proper risk assessment to propose how the lower safety distances pose no critical risk.	- Distance calculation/semi quantitative risk analysis instead of distance requirements for H2 storage acc. to Vlarem II - We are (also on ISO level) arguing for the integration of a general term/general requirements in the respective codes to allow the station supplier/operator to set up the station following his own thorough risk assessment and hence his suggested sufficient safety distances. If the supplier/operator cannot/will not provide his own, standard distances shall apply. - Harmonization within the EU/internationally would help to provide cost efficient standardized products.	- Difficult to say at current stage, but might get expensive (several 100k€) if the pump container has to be moved (significantly) away from the hydrogen tanks.

	Q1	Q2	Q3	Q4
	Q1. Applicable regulations, codes and Standards	Q2. Encountered hurdles for specific designs	Q3. Options for changing regulations	Q4. Cost of regulations
		- Please give a summary of RCS-related issues encountered and solutions deployed per country. - If significant additional complexity is added to designs or the deployment of	- Please provide a description of areas where regulations have unnecessarily hindered the design or would hinder construction or other works (particularly where there would be merit in changing these regulations). Where changes to	- Where regulations which you feel are unhelpful have been identified in the design, is it possible to provide a budget estimate of the cost of complying with the regulation (this will help making the case for a change in the
Hamburg 1 & 2	- Air Products internal standards (EIGA 06-02 E (LH2) and EIGA 15-06 E (GH2)) for separation distances. - General legal framework that could be applied upon hydrogen infrastructure sites in Germany including: Federal Immission Control Act (Bundes-Immissionsschutzgesetz (BImSchG)), Federal Immission Control by-law (Bundes-Immissionsschutz-Verordnung (4. BImSchV), Hazardous Incident Ordinance (Störfall-Verordnung 12. BImSchV), Environmental Impact Assessment Act (Gesetz über die Umweltver-träglichkeitsprüfung (UVPG)), Ordinance on Hazardous Substances (Gefahrstoffverordnung GefStoffV).	- Expert survey by INBUREX on safety issues and distances finalized before project kick-off. Delivery with 200 bar and 400 bar trailers and a mixed concept with production and delivery have been evaluated. Safety distances are already defined and considered in the planning process for the functional demands of the depot. Safety distances have limited the possible space for H2-components and defined the determined area is a result of these safety considerations. - Since this expert safety survey has been completed, site specification parameters have been changed significantly. Actual site specification parameters shall be adapted to all necessary safety issues.	- All regulations can be complied with in the studies.	- None considered.
London	- Air Products internal standards (EIGA 06-02 E (LH2) and EIGA 15-06 E (GH2)) for separation distances. - General legal framework for dangerous goods apply including Control of Major Accidents Hazards 2015 (COMAH 2015) lower tier (5 < tons hydrogen on site < 50), Applicable PED and ATEX regulations, Blue Book guidelines.	- None at this stage. - COMAH will have implications on the permitting procedure and safety processes/administration. Also, site specific safety cases will have to be developed in a detailed engineering phase, comprising Quantitative Risk Assessment, Vent dispersion analysis, ATEX zoning. - This is not part of a basic engineering study, but requires a detailed engineering approach.	- None considered.	- None considered.
Madrid	- Specific design codes (APIs, ISO, IEC, TEMA, NFP, SAE) for hydrogen production facilities and specific Spanish regulation (Royal Decrees) for electrical installations and use of gaseous fuels and safety procedures for construction O&M. - See original spreadsheet for full list of RCS.	- The most significant hurdle encountered has been the absence of a specific legal framework for HRS legalisation. - RD 919/2006 was used as the most relevant regulation that is believed to match future HRS legislation.	- All the regulations and codes used have been helpful. - In order to accelerate the legalization of the HRS, the most interesting adaptation or changes should be in a local regulations	- SAE J2601-2 HD has been bought.
Oslo/Akershus	'- All hydrogen installations shall be designed according to the governing laws and regulations in Norway - Single components in the plant shall be CE-marked where relevant. The whole plant may not be CE-marked if it is assembled and operated by plant owner, e.g. HYOP. - The hydrogen plant shall not lead to impurities in the hydrogen that comes in to conflict with the requirements in SAE J2719. Trucked in hydrogen must meet the same requirements. - See original response for full list of relevant RCS.	- Large quantities of hydrogen stored (>5,000 kg) will require additional measures. The design basis for a 50 bus station will be below this limit. For a 100 bus station, we will need to enter discussions with the authorities to agree on spesific design.	- We believe the current regulations are acceptable for our work.	- No large buracracy has been encountered
Potsdam	- Landesbauordnung Brandenburg (State Building Regulations of Brandenburg) - Bundesimmissionsschutzverordnung (Federal Emission Control Act) - Personenbeförderungsgesetz (Public Transport Act)	- To store 3t of hydrogen onsite, the operator must obey the Federal Emission Control Act for approval of the plant. - To store 5t hydrogen onsite, the operator must obey the Major Accident Ordinance for approval of the plant. - Storage capacities below 3t are handled via the provincial building regulations.	- It is recommended to approve those complex systems via the Federal Emission Control Act, as civil servants at the "Landesumweltamt" (Federal Environmental Agency) are more familiar with such topics which makes the approval process easier.	- Costs for an approval via Federal Emission Control Act are calculated on a basis of the construction costs. In Brandenburg the rate is about 0.35% of the erection costs.
Riga	- A safety distance of 25m is required around the HRS and fencing is required from a minimum of 50m from the HRS of residential or industrial buildings are nearby. - Refuelling protocol ISO 17268, Cabinet of Ministers regulation "Fire safety rules", Constraction Standart LVS NS GS 06-2006 (natural gas fuelling stations and dispensers), ISO/TS 20100:2008 – (gaseous hydrogen - fuelling stations).	- Building permit authority stated that safety distances stipulated by ISO regulation are not valid. Instead, minimum safety distances must adhere to the "law of safety distances" which are greater than in the ISO regulation. The "law of safety distances" does not regulate hydrogen but has been interpreted for the concept and engineering study.	- Hydrogen refuelling infrastructure is not regulated by Latvian law. It would be beneficial to implement safety distance rules in the 'law of safety distances' and to implement a new standard.	- Law of Safety distances' stipulates that an HRS must be located in a suitable area which may present difficulties for future hydrogen infrastructure deployments.
Stuttgart	- Most relevant German regulations are BImSchG and 12. BImschV / Störfall Verordnung (5t hydrogen), ATEX-Zones, BetrSichV. - Refuelling Protocol SAE J2601-HD, ISO 17268 (aligned to SAE J2601-HD, ISO 17268).	- 12. BImSchV led to the requirement of less than 5 t H2 stored at bus depot. Otherwise the administrative effort would be too high for bus operator. - German renewable energy act influenced chosen concept: goal was reduction of EEG-fee (Anlage 4 zu §64 EEG 2014), grid fee according (EnWG §118) and Energy tax (§9a Abs. 1 Nr. 1 StromStG).	- It is hard to judge if the limitation of 5 t hydrogen is necessary or not. Moreover, it seems not easy to change this regulation. - Current EEG-fee, electricity-taxes and additional electricity-fees dramatically increase the hydrogen prices as a renewable fuel for emission-free mobility. This is hindering new green technologies to compete with existing carbon based transport.	- Requirement of <5 t stored hydrogen caused no additional costs but excluded engineering options, beforehand. - Depending on the annual EEG-fee, hydrogen prices can rise more than 3 EUR/kg.
Wuppertal	- The selection of all parts for the HRS is mainly based on two aspects. All components whether located inside or outside of the building need to be CE certificated. Additionally all components needs to be designed to process hydrogen. This means they are applicable for the HRS. - All regulations, Codes and Standards are located on the customer side. Due to the fact that the location is not defined by the time of the study it was not possible to consider RCS for the building itself.	- No hurdles to be managed with	-N/a	-N/a