

Technical Support Document

Multifuel energy stations for cars, buses and trucks

Interreg Baltic Sea Region Project #R032
“Sustainable and Multimodal Transport
Actions in the Scandinavian-Adriatic Corridor”

Work Package	WP2 Clean Fuel Deployment				
Activity	A2.2 Technical support Document				
Responsible Partner	RISE and Skåne Association of Local Authorities				
Author	Erik Wiberg, Peter Bremer				
Version	RC 10	Date	31.10.18	Status	Final

Index

1	Index of tables	4
2	List of abbreviations	5
3	Executive Summary	7
3.1	Key findings	7
3.2	Conclusions	8
3.2.1	Technical and economical perspectives	8
3.2.2	Safety perspective	9
3.3	Recommendations	10
4	Introduction	12
4.1	Aim of the study	12
4.2	Methodology	13
4.3	Definition of Multifuel energy station	14
4.3.1	Sweden	15
4.3.2	Denmark	15
4.3.3	Norway	15
4.3.4	Germany	16
4.3.5	Finland	16
5	Concepts for multifuel energy stations	17
5.1	Car/light duty truck multifuel energy station	17
5.1.1	Technical considerations	17
5.1.2	Safety considerations	17
5.1.3	Financing	18
5.2	Heavy duty truck multifuel energy station	19
5.2.1	Technical considerations	20
5.2.2	Safety considerations	20
5.2.3	Financing	20
5.2.4	Bus multifuel energy station	20
5.2.5	Technical considerations	21
5.2.6	Safety considerations	21
5.2.7	Financing	21
5.3	Obstacles and remedies	22
6	Synergies in combining fuels	23
6.1	Combining fast charging with hydrogen production	23
6.2	Reforming CNG to CH ₂	23
6.3	Hythane	24
6.4	Methanation of hydrogen	24
6.5	Maintenance and inspection synergies	24
6.6	Additional services	24
7	Safety for multifuel energy stations	25

7.1	Introduction.....	25
7.2	Explosion risks	26
7.2.1	Introduction.....	26
7.2.2	Properties for fuels related to explosion risks	27
7.2.3	Ignition sources and general principles to avoid explosions.....	30
7.2.4	Explosion risk considerations related to clean fuels	32
7.2.5	Concept for a multifuel energy station – Safety aspects to be considered.....	55
7.2.6	Legislation according to EU provisions and standards related to safety	59
8	Annexes.....	63
8.1	References.....	63
8.2	References and complementary information for Table 4.....	64

1 Index of tables

Table 1 - Safety related properties of fuel gas (incl. vapour from liquid fuels)	27
Table 2 - Equipment group	28
Table 3 - Temperature class	29
Table 4 - Safety-related data for the properties of some fuels (for the gas phase)	29
Table 5 - European user standards for classification of hazardous areas, installation, inspection, maintenance, repair etc.	33
Table 6 - Zones in hazardous areas	33
Table 7 - Specifications for CH ₂ fuelling stations	37
Table 8 - Example of safety distance requirements in Germany and Sweden according to ISO/TS 19880-1	40
Table 9 - Standards for CNG fuelling stations	44
Table 10 - Standards for LNG fuelling stations	49
Table 11 - Examples of coordination related to the use of multiple fuels in multifuel energy stations ..	55
Table 12 - Common standards/specifications for fuelling stations providing clean fuels	57
Table 13 - Specific product directives related to safety for products to be considered for fuelling station equipment	60
Table 14 - General product directives related to safety for consumers	60
Table 15 - Specific user directives related to safety for workers to be considered for fuelling stations	61
Table 16 - Safety related data for the properties of some fuels (incl. references)	64

2 List of abbreviations

CBG – Compressed biogas
LBG – Liquefied biogas
CNG – Compressed natural gas
LNG - Liquefied natural gas
CH₂ - Compressed hydrogen
LH₂ - Liquefied hydrogen
BEV – Battery Electric Vehicle
HRS – Hydrogen Refuelling Station
SE – Sweden
NO – Norway
DK – Denmark
FI – Finland
DE – Germany
MES – Multifuel energy station
SMR – Steam methane reforming
OPEX – Operational expenditure
CAPEX – Capital expenditure
ISO - International Organization for Standardization
CEN - European Committee for Standardization
CENELEC – European Committee for Electrotechnical Standardization
IEC - International Electrotechnical Commission
FCEV – Fuel cell electric vehicle
E85 – Fuel based on 85 % ethanol
HVO - Hydrogenated Vegetable Oil
MESG - Maximum experimental safe gap
MIC - the Minimum Igniting Current
LFL - Lower Flammable Limit
UFL – Upper Flammable Limit
LEL – Lower Explosive Limit
UEL – Upper Explosive Limit
ATEX – ATmosphères EXplosibles (French), Explosive atmosphere
LPG - Liquefied Petroleum Gas

QAR - Quantitative Risk Assessment

HAZID - Hazard identification

HAZOP - Hazard and operability study

FMEA - Failure mode and effects analysis

FTA - Fault tree analysis

SWIFT - Structured "What-if" technique

DIN - Deutsches Institut für Normung (German standards institute)

3 Executive Summary

The report discusses the positive and negative effects of co-locating clean fuels with each other or with conventional fuels at multifuel energy stations (MES). The fuels considered as clean are CBG/CNG, LBG/LNG, hydrogen and fast charging of electrical vehicles. For hydrogen, CH₂ has been considered in the study. However, to some extent aspects related to LH₂ have been considered also. Multifuel energy stations are also referred to as “multifuel stations” and “multi energy stations” in this report.

We have identified three station types; car station, truck station and bus depot. Those three use different fuels to some extent which also impact safety measures and station layout. Safety aspects with focus on explosion risks have been studied for the different clean fuels present at multifuel energy stations, as well as technical aspects of co-locating such fuels. From this material, conclusions have been drawn on the effects of offering clean fuels at multifuel energy stations. Car and bus stations are quite similar, but truck stations differ a bit due to liquefied gas being present and no fast charging is offered.

The study and this report cover Sweden (SE), Norway (NO), Denmark (DK), Finland (FI) and Germany (DE) located along the Northern Scandria@Corridor, with the main focus on Sweden. This is a natural part of chapter 7: Safety for multifuel energy stations, and the technical and economical synergies have high transferability in general and they are therefore written in a non-country specific manner.

3.1 Key findings

These are our key findings for multifuel energy stations:

1. We have found that it is possible to build a multifuel energy station, and that combining fuels gives several advantages.
2. The definition of multifuel energy stations differs considerably, and there are very few such stations.
3. It is recommended that an international ISO standard is to be developed for multifuel energy stations for vehicles (MES) and adopt such a standard as a European standard.
4. Fuel distribution can be more effective, and several fuels can even be converted on site (i.e. hydrogen from electricity or methane)
5. Resources can be used more efficiently, e.g. electrical grid used for fast charging can be balanced by hydrogen production in an optimal way.
6. Customer services such as restaurants and restrooms can be shared which decreased costs.
7. Maintenance and inspection of equipment can be coordinated in a cost-effective way e.g. travelling time for personnel can be reduced when one technician can service both methane and hydrogen equipment.
8. Safety wise it is feasible to build the three refuelling stations proposed in the study if the correct safety measures are being taken.
9. It has been found that certain technical aspects for a multifuel energy station are well harmonized by international standards and European provisions (e.g. generic standards for explosion protected equipment), while other technical aspects are not.
10. There is a lack of a common harmonized specification of technical requirements for multifuel energy stations, which takes into account safety aspects related to the interaction of different fuels and energies provided by a multifuel energy stations, and which equates the requirements for different fuels where possible.

Different requirements in different countries complicate the development of multifuel energy station infrastructure. Current national differences are recommended to be minimized as far as possible by a

common European standard for multifuel energy stations, with normative requirements for installations (e.g. quantified safety distances) and classification of hazardous areas (e.g. quantified extent of zones). Such a standard should include clean fuels such as CNG, LNG, CH₂, LH₂ and electrical charging of vehicles, and also conventional fuels as far as possible.

3.2 Conclusions

There are many advantages in combining fuels; administrative such as optimising maintenance and inspections as well as technical such as lowering electrolyser loading when a car needs fast charging in order to co-use grid connection, or by reforming CBG/CNG on site to hydrogen to decrease transportation. There are also some safety concerns while combining fuels, which can be overcome. There are not enough multifuel energy stations currently to be able to draw any conclusions from an operations point of view. To date there are only a few MES being built, so the business case needs to be further developed for MES when data and information is available from those being built.

However, there are certain things that should be kept in mind regarding safety when adding new fuels to a fuelling station e.g. ratings related to explosion properties such as equipment group and temperature class differs between the different fuels. For such differences, care must be taken to avoid hazardous areas emanating from one fuel to interfere with hazardous areas or equipment related to another fuel, unless the safety aspects caused by such interference have been adequately covered. Explosion protected equipment suitable for installation and use in hazardous areas emanating from a fuel, may not be suitable for hazardous areas emanating from another fuel. For example, dispensers for petrol, CBG/CNG and hydrogen should be placed outside the hazardous zone of each other.

3.2.1 Technical and economical perspectives

Some synergies can be found when combining several fuels at one refuelling station. Below some of them are described.

Fast charging and H₂ production

By utilising the same grid connection for both fast charging and production of hydrogen via electrolysis, the costs are lowered considerably. By regulating hydrogen production when fast charging is used, less stress is put on the grid as well. The grid cost of adding fast charging to a hydrogen refuelling station will be quite marginal if this is being done in an optimal way. Also, it makes controlling the grid more flexible and allows more fast charging spots within the same grid capacity.

Reforming CNG to CH₂

To facilitate distribution of fuels and if CBG/CNG is available in excess, one option is to reform methane to hydrogen on site via SMR (Steam methane reforming) at the refuelling station. By doing this, only CBG/CNG is delivered and together with hot steam from a water connection and electricity provides hydrogen. This makes fuel distribution easier and since CNG is currently more common than CH₂ this concept could act as a facilitator for CH₂ introduction.

Methanation of hydrogen

By combining hydrogen with carbon dioxide, it is possible to form methane (Sabatier reaction). This is usually done at large scale plants but could be developed for small-scale on-site production as well. To do this CO₂ must be transported to the station, either by pipeline if there is such a producer nearby, or by trucking it in tubes. Were by-product hydrogen is present, this could be a good solution to spread the filling station cost over a larger quantity of fuel, since there are more CNG vehicles than CH₂ vehicles.

These synergies can drastically affect the business case for renewable fuel, therefore it is recommended that a multifuel approach is being considered to improve the business case and lower the costs for infrastructure. Funding options for MES should also be further investigated, compared to funding separate fuelling infrastructures.

3.2.2 Safety perspective

No major safety-related obstacles related to explosion risks have been identified in the study, which prevent combining the clean fuels (incl. charging of electrical vehicles) with each other or with conventional fuels in multifuel energy stations, provided best practice according to applicable international standards and specifications are considered in a competent way. Furthermore, combining fuels in a multifuel energy station provides synergies and coordination possibilities as exemplified above. This means that all the concepts for multifuel energy stations are viable.

For each fuel specific portion of a multifuel energy station, there are suitable international standards and specifications to be used. However, some of the international standards/specifications are not fully harmonized, as national standards/specification in the actual countries (SE, NO, DK, FI and DE). Some will form basis for coming European standards, which will be implemented as national standards/specification in the actual countries (SE, NO, DK, FI and DE). There are also some differences between the countries according to national provisions and code of practice, related to installations (e.g. safety distances for hydrogen stations) and procedures for permit, notifications and inspections. Companies investing in multifuel energy stations, who cooperate and agree on certain standards/specifications to be fulfilled, can contribute to a harmonization in practice, by demanding such standards/specifications to be fulfilled in procurements.

There are a number of common European generic standards which are implemented nationally in the actual countries including harmonized standards for the design and testing of explosion protected equipment, and for the installation, use, maintenance etc. of such equipment (according to Table 5). The identified fuelling station standards for clean fuels refer to such European standards or corresponding international standards (on which the European standards are based on) to a high degree. This facilitates and paves the way for common requirements for multifuel energy stations, which facilitate the establishment of such stations in the actual countries (SE, NO, DK, FI and DE).

To further support the development of an infrastructure with multifuel energy stations, an international ISO standard for Multi Energy Stations (MES) for vehicles is recommended to be developed and adopted as European standard. Such a standard should cover not only CBG/CNG, LBG/LNG, CH₂ and fast charging, but also LH₂ considering the interest of using such fuel for e.g. heavy trucks. Such a standard is recommended to be designed for stations with any combination of fuels (incl. stations with a single type of fuel and – if possible - stations with conventional fuels), thus replacing the current fuel specific standards for stations. Such a standard will provide a common structure of requirements and methodology to be applied regardless of fuel type, facilitating the design and verification of MES. In case of no suitable internationally or regionally recognized standards for fuelling stations with conventional fuels, to base requirements on for MES providing conventional fuels, it might be appropriate to exclude conventional fuels in a first edition of standard for MES and to consider aspects

related to conventional fuels in a next edition depending on the possibilities to agree on aspects and requirements related to conventional fuels.

Requirements and methodology which are common for different fuels - and coordination aspects related to providing fuels with different safety-related properties - can be addressed in an effective and transparent way in such a standard for MES. Current national differences are recommended to be minimized as far as possible by such a standard, by normative requirements for installations (e.g. quantified safety distances) and classification of hazardous areas (e.g. quantified extent of zones).

Current safety distances could in some countries pose a threat to MES since equipment needs to be placed with great safety distances. In other countries, however, the safety distances are short and pose no such threat. This underlines the need for harmonisation. If a MES is to allow for large safety distances, land use could be a problem in densely populated areas due to availability of large enough land and high real estate prices.

3.3 Recommendations

Regarding the technical aspects and financing, the following is recommended:

- Further development in small scale reforming units as well as methanation would be of interest.
- Combining the production of H₂ by electrolysis with fast charging on multifuel stations and optimising the way an electrolyser is controlled when operated in conjunction with a fast charger.
- Funding options for MES should also be further investigated, compared to funding of separate fuelling infrastructures.

The synergies according to these recommendations, can drastically affect the business case for renewable fuel. Therefore, a multifuel approach should be considered to improve the business case and lower the costs for infrastructure.

An important prerequisite for facilitating the deployment of infrastructure for multifuel energy stations is to develop harmonized technical specifications for safety aspects of such stations, according to chapter 3.1.

To initiate the development of an international standard for multi energy stations for vehicles (MES), it is recommended to develop a first draft of such a specification based on the experiences and results of this project on best practice for MES. Such a draft should then be submitted to ISO, with a request to start the development of an international standard for MES. In case ISO would not start such a work, there is the option to do this in a similar way on European level, by approaching CEN.

The following activities are recommended to be included in such a project, to develop a first draft standard for MES:

- Develop a structure for such a standard which aligns as close as possible to the structures of the existing ISO standards/specifications for fuelling stations providing clean fuels such as CNG, LNG and CH₂
- Compile the requirements according to these existing ISO standards/specifications into a draft standard for MES.

- Add requirements related to LH2 into the draft standard.
- Add requirements related to electrical charging of vehicles into the draft standard.
- Examine the existence of appropriate standards/specifications for fuelling stations providing conventional fuels (international, regional or national standard/specification for petrol filling stations) and requirements in such standards. Examine the possibilities to include requirements and/or aspects for such stations/fuels, into the draft standard for MES. Proceed and finalize the first draft standard for MES, based on the results of these examinations.
- Prepare and approach ISO and/or CEN, as described above.

4 Introduction

The major objective of Scandria@2Act is to foster clean, multimodal transport through the corridor regions to increase connectivity and competitiveness of corridor regions while at the same time minimizing negative environmental impact induced by transport activities.

The market for vehicles using clean fuels increase every day. Along the ScanMed.corridor there is no specific fuel that is always preferable, but a mix of fuels would be best suited to meet this increasing demand. In this report we describe the positive and negative effects of co-locating clean fuels with each other at what we call *multifuel energy stations* (MES). An in-depth analysis of safety considerations based on current refuelling station standards is conducted. The clean fuels considered are CBG/CNG, LBG/LNG, CH₂ and fast charging of battery electric vehicles (BEVs). To some extent aspects related to LH₂ have been considered as well. In addition to clean fuels, a multifuel energy station may also provide conventional fuels such as diesel and petrol.

Disclaimer

While all reasonable efforts are made to ensure that the content of this report is accurate, the authors and organisations participating in the development and issue of this report (parties) cannot be held responsible for the way in which the content is used or for any misinterpretations. No liability shall attach to the parties, for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this report or other documents and publications referred to in the report.

4.1 Aim of the study

The report considers three different refuelling/charging station types; cars, trucks and buses. These will not be co-located but analysed as three different scenarios. Cars, buses and trucks partly use different fuels which also impact safety measures and station layout.

Safety aspects with focus on explosion risks have been studied for the different clean fuels present at multifuel energy stations, as well as technical aspects of co-locating such fuels at one station. From this material, conclusions have been drawn on the effects of offering clean fuels at multifuel energy stations.

Car and bus stations are quite similar, but truck stations differ a bit due to liquefied gas being present and no fast charging is offered.

The study and this report cover Sweden (SE), Norway (NO), Denmark (DK), Finland (FI) and Germany (DE) which are all located along the Northern Scandria@Corridor, with the main focus on Sweden. This is a natural part of chapter 7: Safety for multifuel energy stations, and the technical and economical synergies have high transferability in general and they are therefore written in a non-country specific manner.

The first part of the study focuses on definitions and synergies of combining fuel whereas the second part (chapter 7) focuses on safety considerations with the aim to present a concept for multifuel energy stations, by identifying and present safety aspects to be considered for clean fuels and best practice as reflected by common international and European standards and specifications. The study of safety aspects is intended to facilitate design, construction, purchasing and the establishment of safe multifuel energy stations, for increased connectivity and competitiveness of the northern corridor region.

Financial aspects are also considered in the report.

4.2 Methodology

The current situation regarding international and European standards and specifications related to safety for fuelling stations providing clean fuels, have been mapped and those considered as best practice for multifuel energy stations have been identified and compiled. After this, analysis of the material by experts in the relevant areas has led to aspects to be considered for the concept of a multifuel energy station. The study has been made with focus on Sweden, considering also the other countries in the Northern Scandria@Corridor (NO, DK, FI and DE). Safety aspects have been considered with focus on explosion risks.

A potential problem is the use of parallel practices partly addressing the same safety aspects, where care must be taken to adequately observe any mismatch between the practices e.g. practice according to TSA 2015 issued 2015 in Sweden for methane gas filling stations versus practice according to the Swedish standard SS-ISO 16923 issued 2017 for CNG stations, as described in chapter 7.2.4.3.

Local topology and a number of other local specific parameters plays a vital role in how risks are calculated, and which safety distances are needed. Furthermore, non-harmonized requirements between countries provide challenges, exemplified by different requirements on safety distances according to Table 8. Unfortunately, this makes it difficult or impossible to illustrate a concept by a representative and detailed comprehensive layout for a multifuel energy station. To visualize a concept in such a way could otherwise provide a good guidance on aspects to be considered for the layout of a multifuel energy stations. Instead, the report includes information needed for performing a specific safety study in any of the countries studied, which should speed up that process considerably and give the reader a comprehensive understanding on which standards to be used with regard to safety.

The study includes chapters regarding synergies with combining fuels, based on previous experiences by the authors.

In the first part of the report, different fuelling station concepts for cars, trucks and buses are analysed with respect to both synergies and safety aspects.

Three multifuel energy station concepts are discussed and proved viable for each vehicle type; Car/light truck, trucks and buses. This is where conclusions from the safety chapter (7) is integrated to the discussion to investigate what is possible and safe, considering also technological and economical point of views. In the second part of the report, chapter 7, details related to safety aspects are studied.

4.3 Definition of Multifuel energy station

Since the definition *multifuel station* must refer to something new to have an actual meaning, a station for only conventional liquid fuels is not relevant. Liquid fuels have been co-located for a long time with i.e. diesel and petrol. Clean fuels should be a part of the multifuel energy station if they are to be seen as a sustainable asset, since the industry and public bodies agree that they are necessary to achieve good air quality in the cities. The term *multifuel* implies that at least two fuel types are available.

As it can be debated whether electricity is a fuel, though undoubtedly a form of energy, the term *energy* is inserted as well, to form the term *multifuel energy station* (MES). Thus in a clear manner not excluding electricity for charging battery electric vehicles (BEVs). This term, and the term *multifuel station* with the same meaning, is used throughout the report.

Some hydrogen fuelling station today are being built at existing fuelling stations for conventional fuels. This is partly because it makes it easier with regulation, partly because the risk of introducing new fuels is lessened at the site if conventional fuels with a steady throughput are offered as well. Based on this, the conclusion has been drawn that this concept will be the case for many sites to come as well.

There is no clear consensus in the different countries (SE, NO, DK, FI and DE) of what a multifuel energy station is, as the term in general seems to be used for marketing rather than to form continuous reliable fuelling networks. There are in most countries just one or a handful of multifuel energy stations, so the term is not in wide use. Both truck and car stations are referred to as multifuel stations and seem to include fast charging and hydrogen as well as some fossil fuels depending on if it is designed for truck or car.

Since this project focus on renewables (with natural gas included since it from an infrastructure perspective is equivalent to biomethane), the fuels considered are compressed hydrogen (CH₂), liquefied methane (LBG/LNG), compressed methane (CNG/CBG) and fast charging. To some extent, LH₂ (liquefied hydrogen) is addressed as well.

However, different fuels are required in different applications. Therefore, three different multifuel energy station types are considered; for car/light truck, truck and bus. Since they will not usually be co-located, the multifuel concept will sometimes only include two clean fuels. For every type of multifuel station to contain at least one clean fuel, the multifuel concepts will use the following fuels:

- Car/light truck: CH₂, CBG/CNG, fast charging
- Truck: LBG/LNG, LH₂
- Bus: CH₂, CNG/CBG, fast charging

Cars/light trucks will probably use gaseous fuels as the power requirement if those are comparably low. Gaseous fuels are also generally cheaper than clean liquefied fuels. It is reasonable to believe that infrastructure will be available so that range is not a problem for these vehicles. Trucks which are heavier requires more power for a longer distance which results in a larger amount of energy needed on board. Here compressed gas will take up too much space from the cargo being transported. In this study truck stations are defined as serving trucks with a larger energy need than can be supplied by compressed gas.

Buses have a high-power requirement, but gas can be stored on the roof to not reduce space for passengers. Since gaseous fuels are cheaper than liquefied clean fuels, they are expected to continue being the preferred fuel for buses.

As introducing hydrogen, fast charging and biomethane at readily available fuelling stations has gained popularity, conventional liquid fuels are also expected to be offered at multifuel energy stations.

Below all countries in the corridor have been listed with their definitions of multifuel stations, when applicable. There are currently far too few stations in the countries to be able to draw any conclusions regarding operational advantages with combining fuels etc., but the text below is what the definition in this report is partly based on. For buses and heavy trucks, no multifuel energy stations are available today in any of the countries.

4.3.1 Sweden

In Sweden *multifuel energy station* is not defined. The term has been used in conjunction with the winter test area in Arjeplog where the strategy is to provide any fuel that OEMs desire to test at the same station. Hydrogen is part of this as well as other gaseous and liquid fuels. The multifuel energy station plans in Arjeplog are driven mainly by serving the OEMs to fulfil their test needs.¹ The term is also used in a CEF application for 13 truck fuelling stations supplying compressed and liquid biomethane, ED95 and HVO.²

The HRS in Arlanda was installed at the site of Sweden's most utilised methane station. The station is mainly used by taxis due to the que system at the airport which favours zero emission and renewable fuel taxis.

4.3.2 Denmark

In Denmark the term multifuel energy station is used mainly for stations providing hydrogen and fast charging, in addition to petrol and diesel. One such station, which first introduced the term in Denmark, is OK Danmarks in Brabrand³. The fast charging is only using 22 kW, stating a full charge will take about two hours.

4.3.3 Norway

In Norway there is no set definition for multifuel energy stations, but the term “energistasjon” (energy station) is generally used for stations with at least 2 renewable fuels. One such station is The Circle K Økern⁴, where petrol, diesel, synthetic bio diesel, bio ethanol and fast charging is available. Since no gaseous fuels are available there, the station differs considerably from the multifuel energy stations proposed in this report. Uno-X will build two MES in Akershus in 2018, including hydrogen, fast charging and liquid fuels. One will be located in Skedsmo municipality, the other one in the municipality of Ås.

Another multifuel energy station is under planning at Alnabru in Oslo, where the main users are expected to be international and regional providers of transport of goods. The station is to supply fast charging, compressed and liquefied biomethane, hydrogen and biodiesel. Photovoltaic (PV) cells are

¹ http://www.arjeplog.se/download/18.2041ec6513a4d6309aea1/1418197638062/Klimat-+och+energistrategi+Ks+2012_55_019.pdf

² <http://biofuelregion.se/projekt/biogas-norr/aktuelt/>

³ <http://www.eof.dk/Aktuelt/Nyheder/2016/multifuel>

⁴ <http://www.klimaoslo.no/2017/03/24/energistasjoner/>

being built on the roof to supply electricity for charging and service functions.⁵ This station was proposed to supply these fuels earlier, but due to tax reasons HVO had such advantages that the other fuels could not be justified. However, Norwegian tax policy for HVO changed in October 2016 which made HVO less attractive, so the station is now planned to commence with the previously suggested fuels.

4.3.4 Germany

TOTAL is building a couple of new filling stations where they also sell hydrogen and electricity for BEVs in addition to petrol and diesel (and some of them CNG/LPG). They call them “Multi-Energie-Tankstelle” (“multi energy filling station”).

4.3.5 Finland

The term *Vaihtoehtoisten polttoaineiden tankkausasema* is proposed in Finnish by Woikoski, which translates to “Alternative fuels refueling station”. No such stations are known of to current date.

⁵ <https://www.oslo.kommune.no/politikk-og-administrasjon/slik-bygger-vi-oslo/energistasjon-alnabru>

5 Concepts for multifuel energy stations

Below are the three concepts outlined in the chapter *Definition*. For each station concept there are synergies with the fuel combinations but also safety considerations needed to be considered. This chapter uses information from the later chapters, especially *Synergies in combining fuels*, as well as the safety chapter (7) further down in the report, as the aim is to combine these to viable multifuel energy concepts.

Each station concept has its own advantages and disadvantages, and they are explained in detail below.

5.1 Car/light duty truck multifuel energy station

Cars/light trucks will probably use gaseous fuels as the power requirement if those are comparably low. Gaseous fuels are also generally cheaper than clean liquefied fuels. It is reasonable to believe that infrastructure will be available so that range is not a problem for these vehicles. Cars also have the largest multitude of conventional fuels at their fuelling stations with diesel, petrol, E85, and sometimes other alternatives as well.

A multifuel energy station for cars supplies the following fuels:

- CH₂
- Fast charging of BEVs
- CNG/CBG
- Diesel, petrol, E85

5.1.1 Technical considerations

For car multifuel energy stations fast charging combined with electrolysis seem like a very viable option if a HRS is planned, especially in an area that allows for a longer break since fast charging takes at least 20 minutes, and hydrogen fuelling only takes three. Therefore, fast charging is usually placed close to road side restaurants etc. and hydrogen fuelling stations like conventional fuelling stations only have smaller shops in conjunction to their facilities.

On-site reforming could be interesting in an early stage of FCEV rollout, especially if methane pipeline is or will be the delivery method to the fuelling station. This requires that small scale SMR becomes fully commercial, and right now that is almost the case with several manufacturers. It also requires small scale compressors for hydrogen to become cheap enough for this; the current status is a bit unclear on that front.

Methanation could be interesting; in early stages of HRS rollout throughput of hydrogen will be low and there are some hydrogen by-product sources available that could be used for car fuels for hydrogen as well as methane, by using methanation for the methane.

5.1.2 Safety considerations

When combining fast charging with any other fuel care should be taken to place the fast charging equipment outside the hazardous areas surrounding fuelling installations according to chapter 7.2.4.5, where further details regarding location of fast chargers on a multifuel energy station can be found. As different fuels have different properties with respect to explosion risks, which imply different requirements on the equipment with regard to explosion protection, equipment for one fuel may not be suitable for another fuel. Therefore, equipment (e.g. a dispenser) used for different fuels need to be

designed with respect to the properties for all the fuels they are used for e.g. designed for the most severe equipment group and temperature class of all the actual fuels. This applies also for equipment used in a hazardous area caused by another equipment using another fuel.

Synergies with respect to these aspects can be attained for example by designing a multifuel energy station such that equipment which are or may be used in hazardous areas, are designed to requirements compatible with the most severe properties of possible fuels foreseen to be used. This needs of course to be balanced against the availability of such equipment and any increasing costs for a higher equipment classification than needed for those fuels which are relevant to be handled in the shorter term.

Further details related to safety considerations and concept for a multifuel energy station, can be found in chapter 7. Since no LNG/LBG or LH2 is present for this station type, hazards specific for such fuels does not need to be considered. Since diesel does not cause an explosive mixture with air due to its flash point, according to the note in Table 4, explosion hazards need not to be considered for diesel.

5.1.3 Financing

Currently there are not many MES for cars in the countries along the corridor. However, there is one in Denmark since June 2016 and two under construction in the Oslo area. In total, this makes experience from OPEX and CAPEX sparse. Also, none of them have CBG/CNG available which limits the possibility to evaluate synergies with CBG/CNG and hydrogen.

In general, a few things can be said regarding financing:

Because of the synergies in combining fuels are mainly evident in operation rather than investment, OPEX would be the main thing that could be lowered by the advantages of MES. Methane is already transported to networks of refuelling stations, which would help the distribution of hydrogen. Either by co-transporting, something that should be further investigated, or by on-site SMR.

When it comes to fast charging, the main financial benefit is to combine it with on-site hydrogen production. Usually, connecting a fast charger to the grid and installing it amounts to 40 % of the total cost ⁶, and if this is done when an electrolyser is installed with shared connection, almost the full 40 % could be saved. During operation, the shared connection requires substantially lower grid fees, which should also help the total business case.

As the vehicle volumes are low and infrastructure demand high, public funding is a vital part of getting MES in place. When applying for such project funding, a MES could qualify for more financing programs in the EU and nationally. On the other hand, it could be that only a specific part of the MES can be financed through each scheme, for example the Swedish support for fast charger deployment that can only be used for fast chargers. This could make it possible to finance the entire MES piece by piece, but more work is needed to apply for funding. There are no known current schemes for public funding of MES, but with that in place the costs would be lower than those for deploying infrastructure for each fuel on its own. This information needs to be made available to politicians in order to

⁶http://www.stockholm.se/Global/Frist%C3%A5ende%20webbplatser/Milj%C3%B6f%C3%B6rvaltning/en/Milj%C3%B6bilar/Dokument/Broschyren%20och%20rapporter/elbilsupphandlingen_dok/Erfarenheter%20fr%C3%A5n%20etablering%20av%20publik%20laddning%20i%20Stockholm.pdf

introduce a support scheme for MES. After this initial public funding, the business case for MES should be favourable as vehicle throughput increases.

Another effect that is not exclusive for MES but for all HRSs with on-site electrolyzers is that oxygen is being produced as a by-product. The oxygen is very pure and with the right consumer could be sold for four times the price of standard purity merchant oxygen. The main user for this high purity oxygen is semiconductor manufacturers. Another consumer with higher and more geographically wide spread demand is hospitals. In urban areas district heating can be connected to the electrolyser to use heat from that process for space heating etc, which also would generate income. Especially since the operators open up the grids more and more for peripheral input. When a MES with on-site hydrogen production is being planned, this should be taken into account since it could change the business case considerably.

When co-locating new fuels with conventional ones such as petrol and diesel, there is an advantage that equipment service as well as facilities such as restrooms are being made available to the consumers using the new fuel even thou the initial volumes are low and does not on its own justify the costs incurred. As the new fuel volumes increase, it follows that the conventional fuels decrease, which makes the number of customers constant. This is a good way for existing refuelling stations to keep customers, and therefore gives them incentive to invest in MES.

The margins for the station operator on selling conventional fuels are generally low, which makes it attractive to introduce fuel which at least when volumes increase can have a larger margin, especially when produced on site. This hold true especially for hydrogen, but could be true for fast charging as well depending on tax regime etc. Currently it looks like the consumers are reluctant to pay high prices for fast charging, and it takes more time than hydrogen refuelling which reduces throughput and revenue stream.

One way to increase the possibility of a profitable business outcome for a refuelling station is to incorporate PV cells at the HRS site. This could remove the cost of electricity tax and therefore decrease operating costs, and at the same time the operating costs will be more stable since they are not influenced by electricity price volatility. If the MES is both connected to the grid and to an on-site PV system, electricity could be sold when favourable and used for hydrogen production at other times or when needed. By doing this, the business case is expanded further.

5.2 Heavy duty truck multifuel energy station

Trucks that are heavier requires more power for a longer distance which results in a larger amount of energy needed on board. Here compressed gas will take up too much space from the cargo being transported. In this study truck stations are defined as serving trucks with a larger energy need than can be supplied by compressed gas (this is i.e. done by Asko in Norway). This does not necessarily mean that heavy duty trucks have a greater mass than trucks using CH₂, however the duty cycle (typically range) requires more energy than can be accommodated in compressed hydrogen. Diesel and HVO are conventional fuels usually used in heavy trucks. CH₂ could be used even for quite heavy trucks, but to make a meaningful differentiation to light trucks, this definition is made.

The truck multifuel energy station, intended for heavy trucks and longer distances, supplies the following fuels:

- LBG/LNG
- LH₂
- Diesel, HVO

5.2.1 Technical considerations

Since liquefied methane as well as liquefied hydrogen requires quite large production facilities to be produced, the productions synergies will probably not be present in the same way as for compressed fuels. On the other hand, heat exchangers, safety enclosure for tanks and other refuelling station components might be possible to construct for dual use.

One other thing worth noting is that cryo distilleries can be used from raw biogas containing both methane and hydrogen, resulting in LH2 and LBG/LNG.

5.2.2 Safety considerations

As different fuels have different properties with respect to explosion risks, which imply different requirements on the equipment with regard to explosion protection, equipment for one fuel may not be suitable for another fuel. Therefore, equipment (e.g. a dispenser) used for different fuels need to be designed with respect to the properties for all the fuels they are used for e.g. designed for the most severe equipment group and temperature class of all the actual fuels. This applies also for equipment used in a hazardous area caused by another equipment using another fuel.

Synergies with respect to these aspects can be attained for example by designing a multifuel energy station such that equipment which are or may be used in hazardous areas, are designed to requirements compatible with the most severe properties of possible fuels foreseen to be used. This needs of course to be balanced against the availability of such equipment and any increasing costs for a higher equipment classification than needed for those fuels which are relevant to be handled in the shorter term.

Further details related to safety considerations for LBG/LNG and concept for a multifuel energy station, can be found in chapter 7. Since diesel does not cause an explosive mixture with air due to its flash point, according to the note in Table 4, explosion hazards need not to be considered for diesel. Since no fast charging is present for this station type, considerations to this need not to be taken. Due to risks of body injury due to extremely low temperatures the presence of LBG/LNG requires extra safety measures according to 7.2.4.4. Similar hazards need to be considered also for LH2, which have even lower temperatures.

5.2.3 Financing

Currently there are no MES for heavy duty trucks. In the financing chapter 5.1.3 above, there are some considerations that could be applied to trucks as well.

5.2.4 Bus multifuel energy station

Buses have a high-power requirement, but gas can be stored on the roof to not reduce space for passengers. Since gaseous fuels are cheaper than liquefied clean fuels they are expected to continue being the preferred fuel for buses. Fast charging is gaining momentum around the world with buses, especially on shorter distances with larger amounts of passengers. Diesel and HVO are conventional fuels usually used in buses.

The bus multifuel energy station supplies the following fuels:

- CBG/CNG
- CH2
- Fast- and overnight charging

- Diesel, HVO

5.2.5 Technical considerations

For buses similar synergies as with cars are present, but bus depots present a bit different possibilities and hurdles. Combining BEV buses and FCEV buses can be done in a more planned manner in a bus depot since driving distances for the individual buses is known. When optimising this in a bus depot buses can, simplified, be charged during night and hydrogen can be produced during day. By doing this the bus fleet can use BEV buses for shorter high-volume lines and hydrogen for longer distances and for flexibility. For bus operators optimising bus usage on the different lines is the main means of competition for procurement, which is why a mix including hydrogen buses is favourable for them.

Because of the scale and predictability of bus energy stations, methanation as well as on site reforming could be more interesting in the bus case than with cars. Bus depots are usually located where this type of facilities can be placed. Hythane is probably most interesting for buses, where it has also been trialled earlier. So, if methanation or SMR is being performed on-site than Hythane could be of interest, but the OEMs must be on track if this is to be possible, since they previously have been reluctant with regards to warranty.

5.2.6 Safety considerations

Basically the same as for the car station: When combining fast charging with any other fuel care should be taken to place the fast charging equipment outside the hazardous areas surrounding fuelling installations according to chapter 7.2.4.5, where further details regarding location of fast chargers on a multifuel energy station can be found. As different fuels have different properties with respect to explosion risks, which imply different requirements on the equipment with regard to explosion protection, equipment for one fuel may not be suitable for another fuel. Therefore, equipment (e.g. a dispenser) used for different fuels need to be designed with respect to the properties for all the fuels they are used for e.g. designed for the most severe equipment group and temperature class of all the actual fuels. This applies also for an equipment used in a hazardous area caused by another equipment using another fuel.

Synergies with respect to these aspects can be attained for example by designing a multifuel energy station such that equipment which are or may be used in hazardous areas, are designed to requirements compatible with the most severe properties of possible fuels foreseen to be used. This needs of course to be balanced against the availability of such equipment and any increasing costs for a higher equipment classification than needed for those fuels which are relevant to be handled in the shorter term.

Further details related to safety considerations and concept for a multifuel energy station, can be found in chapter 7. Since no LNG/LBG or LH2 is present for this station type, hazards specific for such fuels does not need to be considered. Since diesel does not cause an explosive mixture with air due to its flash point, according to the note in Table 4, explosion hazards need not to be considered for diesel.

5.2.7 Financing

Currently there are no MES for buses. In the financing chapter 5.1.3 above, there are some considerations that could be applied to buses as well.

5.3 Obstacles and remedies

Obstacles and remedies related to safety with respect to explosion risks are presented in chapter 7.2.5, with information on applicability for the three different types of multifuel energy stations presented in chapter 5.1.2, 5.2.2 and 5.2.6. The obstacles and remedies are mainly related to:

- Compatibility of station equipment with different fuel properties related to explosion risks.
- Harmonisation of requirements for multifuel energy stations in the actual countries (SE, NO, DK, FI and DE) for the design, construction, operation, maintenance and inspection

For example, multifuel energy stations requires certain space to meet requirements related to different types of safety distances and related to extent of hazardous areas. If space is severely restricted like in large city centres this could pose a problem. Different solutions can be considered for such a problem including;

- Apply reduced safety distances based on e.g. risk assessment or use of fire resistant partitions/walls, if allowed by the applicable provisions

- Use explosion protected equipment or design the station such that the equipment is compatible with the most severe explosion related properties for the actual fuels, to enable equipment to be used closer to sources of release emanating from different fuels.

6 Synergies in combining fuels

The idea of combining fuels is partly to increase exposure and public awareness to make it obvious for vehicle users that there are alternatives to traditional fuels, but also that by combining fuels at the same filling station it is possible to reduce costs and also increase efficiency. Below are some examples of how this can be done and what the outcomes are expected to be, including conversion of a fuel to another, decreasing service costs and providing customer service.

There are other ways to combine fuels such as using high temperature fuel cells to produce electricity from biogas, but those have not been deemed feasible in this study due to economical and resource concerns.

6.1 Combining fast charging with hydrogen production

By utilising the same grid connection for both fast charging and production of hydrogen via electrolysis, the costs are lowered considerably. By regulating hydrogen production when fast charging is used, less stress is put on the grid as well. The grid cost of adding fast charging to a hydrogen refuelling station will be quite marginal if this is being done in an optimal way.

Several studies conclude that fast charging is important for car users, but it will only be used a handful times each year since most of the daily driving has been made possible with only overnight charging as a result of the longer range that comes with larger batteries now introduced. At the same time BEV users seem reluctant to pay a high price for electricity at the fast charging points; partly because of the low costs with overnight charging, partly because fast charging has been free at most charging points so far. That means it is important to keep the cost fairly low, especially in the phase of market introduction that we are currently in. At the same time, multiple fast charging points at the same station are generally required to accommodate sudden surges in demand. This requires a low cost, high power grid connection.

One way to achieve this is to combine fast charging with on-site production of hydrogen at the fuelling station and regulate the electrolyser to reduce production when power is needed for fast charging. This is even more interesting as industry JVs are announcing 350 kW ultra-fast chargers. If a fuelling station today with 720 kg capacity (Linde standard) has an utilisation rate of 70 %, 2-3 350 kW chargers can be used while regulating the electrolyser down, without any additional grid cost. Since the down regulation does not have to be very quick (minutes rather than sub second, which is usually required for grid regulation), most electrolyser types can be operated in this manner.

6.2 Reforming CNG to CH₂

To facilitate distribution of fuels and if CBG/CNG is available in excess, one option is to reform methane to hydrogen on site via SMR at the refuelling station. By doing this, only CBG/CNG is delivered and together with hot steam from a water connection and electricity provides hydrogen.

Most reformers work at a fairly low pressure, around ambient. This has the disadvantage that the hydrogen compressor needs to take the pressure all the way from one bar to around 850-900 bar for refuelling cars or 350-400 bar for refuelling buses or trucks. An electrolyser on the other hand usually provides hydrogen at around 30 bars and possibly up to around 100 bars since the entire system is pressurised. On the other hand, small scale SMR can have a quite small footprint and is less costly than electrolyzers. Since different pressures are being used and fuel cell vehicles driven by hydrogen has a very high purity requirement, the gases need separate compressors.

6.3 Hythane

By combining hydrogen with methane in a combustion engine a higher efficiency and lower emissions can be achieved due to the higher combustion temperature and that the engine can be run leaner. This has been proposed earlier, but due to vehicle warranty voiding, a lack of hydrogen infrastructure and increasing methane engine efficiency, this idea has largely been abandoned. However, with combined fuelling for methane and hydrogen, this could easily be realised to a low cost at a multi fuel station.

6.4 Methanation of hydrogen

By combining hydrogen with carbon dioxide it is possible to form methane (Sabatier reaction). This is usually done at large scale plants, but could be developed for small scale on site production as well. To do this CO₂ must be transported to the station, either by pipeline if there is such a producer nearby, or by trucking it in tubes.

As methane is used in engines with lower vehicle efficiency than hydrogen in fuel cells, as well as the Sabatier process has some energy losses, this pathway is mainly interesting in a stage where methane is more widely used as a fuel than hydrogen. Therefore, it might not be a viable option when FCEVs are widespread. However; if miniaturised it might be interesting in sparsely populated or peripheral areas where the usage for each fuel is low but the area of uptake is large.

6.5 Maintenance and inspection synergies

Subcontractors that are contracted for the service and maintenance of CBG/CNG stations usually have or could be required to do the same for CH₂ stations. The same authorities also inspect CBG/CNG stations. Coordination of maintenance and inspection as outlined in chapter 7.2.5.1, should be feasible. Co-locating such stations should lower these costs considerably.

6.6 Additional services

When combining several fuels at the same fuelling station there are also synergies in additional services such as restaurants, restrooms etc. as a larger volume of users will utilise the same facilities and by that bring economies of scale. This could be one of the reasons why more and more hydrogen refuelling stations are located at existing fuelling stations for conventional fuels.

7 Safety for multifuel energy stations

7.1 Introduction

This chapter focuses on safety aspects for multifuel energy stations providing clean fuels such as CH₂, CBG/CNG, LBG/LNG and electrical charging of BEVs, in Sweden, Norway, Denmark, Finland and Germany, with focus on Sweden.

Concepts for multifuel energy stations handling conventional fuels such as petrol and diesel along with CBG and CNG are more or less already in place, considering a number of such established stations in the actual countries. Considering the impact explosion hazards have for a successful deployment of multifuel energy stations with clean fuels, the study is focused on ignition of fuels and related explosion risks to be considered when providing multiple and clean fuels on multifuel energy stations.

The results of the study illustrate a concept for multifuel energy stations by presenting safety aspects and best practice to be considered for multifuel energy stations providing multiple fuels with different properties, including examples of measures and possibilities for coordination related to such aspects.

There are comprehensive national provisions and guidelines in the five actual countries (SE, NO, DK, FI and DE) which are applicable for fuelling stations and different fuels, which need to be considered for multifuel energy stations and concepts thereof. Provisions or guidelines compiled specifically for multifuel energy stations with clean fuels have not been found in the actual countries. Furthermore, the requirements differ in varying degrees between the countries, and internationally recognized specifications and standards for multifuel energy stations with clean fuels, are missing.

Considering these aspects, best practice for the safety related to explosion risks, was considered to be best reflected by a combination of internationally recognized standards and specifications for fuel specific fuelling stations. Such a best practice offers the best possibilities for acceptance among the actual countries considering:

- existing standards/specifications based on international standards/specifications (or such standards/specifications on the way) in the actual countries
- commitments as members in the related international standardization organizations
- commitments to comply with EU provisions

Requirements according to such fuel specific standards and specifications, need to be complemented by safety aspects addressing the interaction between the different fuels and between the fuels and facilities for electrical charging of vehicles.

Based on the above, a common standard for the actual countries is recommended to be developed, which addresses the safety for a multifuel energy station providing different fuels and electrical charging, including aspects related to the interaction between the different fuels/energies, in order to facilitate the deployment of multifuel energy stations providing clean fuels.

7.2 Explosion risks

7.2.1 Introduction

In order to succeed in introducing multifuel energy stations providing clean fuels, it is crucial that such explosion risks for multifuel energy stations are not higher than such risks for fuelling stations with conventional fuels. The clean fuels have different properties with respect to this, which need to be considered in the design of fuelling stations and in the handling of the fuels. Therefore, for the safe design and operation of multifuel energy stations with clean fuels, it is important to understand the properties with respect to explosion for the different fuels, how these properties differ between different fuels and what these differences mean for a multifuel energy station.

Important risks to consider for fuelling stations, are risks for explosion due to ignition of flammable gas from fuels mixed with air. The two main hazards caused by such explosions, are:

- thermal effects (e.g. heat from flames)
- blast effects (e.g. pressure waves)

Chapter 7.2.2 describes explosion properties of flammable gas and vapours. The risk for explosion is not only related to such properties for the fuels, but also related to ignitions sources. Chapter 7.2.3 gives an overview of ignition sources which - in combination with an explosive atmosphere caused by fuels - can cause explosions. This chapter presents also general principles to avoid and to mitigate explosions. Avoiding ignition sources capable to ignite flammable mixtures of gas with air also reduces the risk for fires caused by ignited flammable gas mixtures. The risk for such ignition sources initiating fires in other combustible materials and substances, is reduced as well.

Chapter 7.2.4 deals with explosion risk considerations related to the actual clean fuels (CH₂, CBG/CNG, LBG/LNG and BEV). Standards and specifications representing best practice for the safety of fuelling stations are presented for each fuel. Certain standards are European standards (EN) issued by the European standardization bodies CEN and CENELEC. According to the CEN/CENELEC regulations, the European member countries including the actual countries (SE, NO, DK, FI and DE), are obliged to implement such standards as national standards. Therefore, common requirements according to such EN standards facilitate the establishment fuelling stations in the actual countries.

Chapter 7.2.5 highlights aspects to be considered for multifuel energy stations with clean fuels, related to properties and requirements for different fuels. Best practice based on standards and specifications are presented, reflecting the concept for a multifuel energy station with clean fuels.

Chapter 7.2.6 describes safety-related legislation according to European Union directives and standards, to be considered for multifuel energy stations.

7.2.2 Properties for fuels related to explosion risks

Important properties for fuels, related to explosion risks, are described in Table 1, Table 2, Table 3 and Table 4. As explosion risks are related to gas incl. vapour, the described properties for liquid fuels are related to the vapour from liquid fuels. The described properties apply under normal atmospheric conditions, if not otherwise stated.

Table 3 does not only presents temperature classes for gases and vapours related to their auto ignition temperatures. It does also present to which extent equipment classified in different temperature classes, can be used with respect to the temperature class of gases and vapours in classified areas.

Table 1 - Safety related properties of fuel gas (incl. vapour from liquid fuels)

Property	Description
Auto-ignition temperature, AIT (°C)	Lowest temperature (of a hot surface) at which under specified test conditions an ignition of a flammable gas or vapour in mixture with air or air/inert gas occurs [1]
Diffusion coefficient in air (cm ² /s)	Diffusion coefficient in air describes how fast a gas diffuses in air. The higher the diffusion coefficient of a gas is, with respect to air, the faster the gas diffuses into air. The diffusion coefficient is a physical constant dependent on molecule size and other properties of the diffusing substance as well as on temperature and pressure. Diffusion in air reduces the gas concentration in air. Therefore, gas diffusion will cause the gas mixture with air to approach the density of the air, and air with low gas concentration will tend to move with the air.
Equipment group	A gas or vapour is classified into one of three equipment groups (IIA, IIB or IIC) depending on its minimum ignition energy, according to Table 2. The minimum ignition energy is determined by the maximum experimental safe gap (MESG) or the minimum igniting current (MIC), according to ISO/IEC 80079-20-1. I.e. the groups are the result of MESG or MIC ratio determination except where there is no value listed for MESG or MIC ratio, where the group may be based on chemical similarity. Other terms used synonymously with "Equipment group" are: "Explosion group", "Gas group" or just "Group"
Flammability range (volume %).	To ignite a flammable gas requires the gas to be mixed with a certain minimum amount of air (to provide oxygen for oxidation) and requires also the concentration of gas to not be too high. Flammability range describes the range of gas concentration (volume %), within which the concentration of flammable gas, vapour or mist in air, is explosive. The range is limited by the lower flammable limit (LFL) and upper flammable limit (UFL), defined in IEC 60079-10-1 [2] Other terms used synonymously with "Upper flammable limit (UFL)" and "Lower flammable limit (LFL)" are: "Upper explosive limit (UEL)" and "Lower explosive limit (LEL)" Another term used synonymously with "Flammability range" is: "Explosion range"
Relative density of a gas or a vapour, RDT	Density of a gas or a vapour relative to the density of air at the same pressure and temperature (air being equal to 1,0). [3] A gas with lower density than air (i.e. relative density <1) tends to move upwards, while a gas with higher density than air tends to move downwards. If the temperature of the gas differs from the temperature of air, the gas may

	<p>have other densities which affect the behaviour. For example, if a gas with lower density than air (at the same temperature as air), is colder than the air, it may move slower upwards or even move downwards due to an increased density caused by the lower temperature. Moving downwards may cause gas to accumulate at ground level and/or underground confinements.</p> <p>Dilution of a gas in air causes a mixture of gas with air to approach the density of air, which aligns the movement of gas with the movement of air.</p> <p>A gas at high pressure escaping into the atmosphere may be strongly cooled as it expands, causing the density of the gas to increase.</p> <p>For practical applications, a gas mixture which has a relative density below 0,8 is considered as being lighter than air (e.g. methane and hydrogen). If the relative density of a gas or vapour mixture is above 1,2, it is considered as being heavier than air.</p>
Temperature class	<p>The temperature class of a gas or vapour is related to the auto-ignition temperature according to a table in IEC 60079-14. [4] [5]</p> <p>A gas or vapour is classified into one of six classes (T1, T2...T6) depending on its auto-ignition temperature, according to Table 3, replicating the table in IEC 60079-14.</p>
Minimum ignition energy, MIE (mJ), in air	<p>Properties related to spark energy required for igniting a mixture of gas with air, are normally described by one of the following parameters:</p> <ul style="list-style-type: none"> - Maximum experimental safe gap (MESG) - Minimum igniting current (MIC) <p>These parameters are used to classify gas in equipment groups according to the description above for "Equipment group".</p> <p>However, minimum ignition energy expressed in Joule (J, mJ, µJ) can also be found in the literature and standards for explosion protected equipment.</p>

Table 2 - Equipment group

Equipment group	Characteristics
IIA	MESG ≥ 0,9 mm, or MIC > 0,8
IIB	0,5 mm < MESG < 0,9 mm, or 0,45 ≤ MIC ≤ 0,8
IIC	MESG ≤ 0,5 mm, or MIC < 0,45
<p>Note MESG: Maximum Experimental Safe Gap, determined according to ISO/IEC 80079-20-1 MIC: Minimum Igniting Current, determined according to ISO/IEC 80079-20-1</p> <p>Gas classified IIC are more ignition sensitive than gas classified IIB, and IIB gas are more sensitive than IIA gas. I.e. gas classified IIC can be ignited by a spark with lower energy than required for gas classified IIB and IIA.</p>	

Table 3 - Temperature class

Temperature class required by the area classification	Auto-ignition temperature of gas or vapour in °C	Allowable temperature classes of equipment
T1	> 450	T1 – T6
T2	> 300	T2 – T6
T3	> 200	T3 – T6
T4	> 135	T4 – T6
T5	> 100	T5 – T6
T6	> 85	T6

Table 4 - Safety-related data for the properties of some fuels (for the gas phase)

Substance	Density relative to air	Diffusion coefficient in air (cm ² /s)	Flammability range LFL-UFL (volume %)	Auto-ignition temperature (°C)	Temperature class	Minimum ignition energy in air (mJ)	Equipment group
Ethanol	1,59	0,11	3,1–19,0	400	T2		IIB
Hydrogen	0,07	0,61	4,0–77,0	560	T1	0,016	IIC
LPG	1,57	0,10	2–10		T2		IIA
Methane	0,55	0,16	4,4–17,0	595/600	T1	0,28	IIA
Petrol	3,0	0,05	1,4–7,6	280	T3	0,24	IIA
Propane	1,56	0,12	1,7–10,9	445	T2	0,25	IIA
Vehicle gas	0,6	0,16	4–17		T1		IIA

Notes

For references and additional information, refer to Table 16, chapter 8 (Annexes). Table 16 includes also some additional fuels: biogas with approx. 65 % methane and natural gas with approx. 87 % methane.

A rough indication of explosion risks under normal ambient conditions, is indicated by colours:

- green colour indicating values which normally reduces the explosion risk, compared with the corresponding values for the other fuels.
- red colour indicating values which normally increases the explosion risk, compared with the corresponding values for the other fuels.

Diesel fuel is not included in the table because at normal ambient temperatures in the actual countries (SE, NO, DK, FI and DE) it cannot cause an explosive mixture with air due to its flash point (>+60 °C according to the Swedish handbook: SEK Handbook 426 ed. 5, and +38 °C to +96 °C for diesel oil no. 1 and 2 according to ISO/IEC 80079-20-1:2017)

7.2.3 Ignition sources and general principles to avoid explosions

The following general principles, in order of priority, apply to prevent and protect against explosions:

1. *Minimize the likelihood of an explosive atmosphere*
2. *Minimize the likelihood of ignition sources*
3. *If explosion cannot be avoided, halt it immediately and/or limit the explosion flames and pressure to a sufficient level of safety*

These principles reflect the principles of integrated explosion safety according to the ATEX Directive 2014/34/EU, Annex II, for products intended for use in potentially explosive atmospheres. They reflect also the basic principles to be considered for employers, according to Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

Measures to minimize the likelihood of an explosive atmosphere can be for example:

- minimizing likelihood of release in pipe connections, by minimizing the number of such connections and by using gas tight connections with an appropriate quality
- increase natural ventilation in enclosed spaces by suitable openings in walls and ceilings

Measures to minimize the likelihood of ignition sources can be for example:

- by using CE marked explosion protected equipment compliant with ATEX Directive 2014/34/EU, properly installed, used and maintained according to the marking, accompanying instructions and applicable code of practice
- by preventing build-up of electrostatic charges
- by applying appropriate instructions and organisational measures for the operation

Measures to halt an explosion and/or limit the explosion flames and pressure, are measures to be applied to mitigate effects of explosions which cannot be avoided. Such measures include for example the use of CE-marked protective systems complying with ATEX Directive 2014/34/EU, for explosion venting, suppression or isolation.

A description of possible ignition sources can be found in the standard EN 1127-1:2011 (Explosive atmospheres – Explosion prevention and protection – Part 1: Basic concepts and methodology). The standard describes the following ignition sources:

- Hot surfaces
- Flames and hot gases
- Mechanically generated sparks
- Electrical apparatus
- Stray electric currents and cathodic corrosion protection
- Static electricity
- Lightning
- Radio frequency (RF) electromagnetic waves
- Ionizing radiation
- Adiabatic compression and shock waves
- Exothermic reactions

Typical ignition sources for electrical equipment are sparks and arcs due to short circuits and breaks in electrical circuits, and high surface temperatures caused by electric power. Such short circuits and

breaks can be intentional (as for switches, disconnectors and contactors) or can be unintentional due to faults and abnormal conditions. The energy in such electrical sparks is related to either current in combination with the circuit inductance (inductive sparks), voltage in combination with the circuit capacitance (capacitive sparks) or current in combination with voltage (resistive sparks).

Typical ignition sources for mechanical equipment are sparks caused by mechanical impact and high surface temperatures caused by friction for moving parts.

7.2.4 Explosion risk considerations related to clean fuels

7.2.4.1 General

Analogous to facilities in general, which handles flammable gas and liquids, the following general approach applies for handling explosion hazards:

1. Perform a risk assessment with respect to the occurrence of explosive atmosphere, resulting in a documented classification of hazardous areas.
2. Use equipment and apply routines appropriate for the hazardous area.

Common European standards for users, reflecting best practice for these aspects, are presented in Table 5. These standards have been implemented as national standards in all the actual countries (SE, NO, DK, FI and DE).

These national standards are user-oriented standards (not equipment standards for equipment manufacturers) and may contain additional national requirements or information. For example, in Sweden the standard EN 60079-10-1 is implemented as a handbook "SEK Handbok 426" which contains the English text of EN 60079-10-1 together with a Swedish translation, complemented by national information e.g. a number of examples on how to classify hazardous areas for different applications.

While national provisions and standards for installation and use of equipment and assemblies, may contain requirements additional to those of common European standards (on which the national standards are based on), member states of EU and EEA are not allowed to apply additional health and safety requirements for the design or additional verification of CE-marked equipment and assemblies complying with harmonized European standards. This is to allow free trade within the EU and EEA market, without barriers.

I.e., for fuelling station equipment and assemblies covered by the ATEX Directive 2014/34/EU and with CE-marking according to that directive, there shall be no trade barriers or technical barriers to supply such equipment and assemblies to the actual countries (SE, NO, DK, FI and DE), considering that all these countries have implemented the directive in their national legislation. This applies also for the other CE-marking directives applicable for fuelling stations.

Therefore, it is recommended to use such equipment and assemblies with CE-marking for multifuel energy stations, in order to facilitate the establishment of such stations in the actual countries (SE, NO, DK, FI and DE). By the CE-marking, the manufacturer certifies that the equipment fulfils the essential health and safety requirements according to all applicable CE marking directives, including ATEX Directive 2014/34/EU for equipment to be used in explosive atmosphere. For example, petrol pumps with electric motors are normally categorized as category 2 electrical equipment according to ATEX 2014/34/EU Guidelines, § 246, which requires such a complete assembly to be examined and certified by a notified body according to the EU-type examination module of ATEX Directive 2014/34/EU.

Table 5 - European user standards for classification of hazardous areas, installation, inspection, maintenance, repair etc.

European standard <i>(IEC standard in parenthesis)¹⁾</i>	Title
EN 60079-10-1:2015 <i>(IEC 60079-10-1:2015)</i>	Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres
EN 60079-14:2014 <i>(IEC 60079-14:2013)</i>	Explosive atmospheres - Part 14: Electrical installations design, selection and erection
EN 60079-17:2014 <i>(IEC 60079-17:2013)</i>	Explosive atmospheres - Part 17: Electrical installations inspection and maintenance
EN 60079-19:2011 <i>(IEC 60079-19:2010)</i>	Explosive atmospheres - Part 19: Equipment repair, overhaul and reclamation
EN 60079-29-2:2015 <i>(IEC 60079-29-2:2015)</i>	Explosive atmospheres - Part 29-2: Gas detectors - Selection, installation, use and maintenance of detectors for flammable gases and oxygen
¹⁾ Corresponding international IEC standard in parenthesis, on which the European standard is based on.	
Note The cited editions were the latest editions at the time of writing this report.	

The extent of a hazardous area according to EN 60079-10-1, is determined by the release of flammable gas in normal and abnormal operation taking into account also routine maintenance. The extent depends also on the properties of the released gas, according to Table 4 above and as described for the clean fuels according to chapter 7.2.4.

Depending on the frequency of the occurrence and duration of an explosive mixture of gas with air, the hazardous area is classified in one of three zones, according to Table 6 below.

Table 6 - Zones in hazardous areas

	Definition ¹⁾
Zone	hazardous area classification based upon the frequency of the occurrence and duration of an explosive atmosphere
Zone 0	an area in which an explosive gas atmosphere is present continuously or for long periods or frequently
Zone 1	an area in which an explosive gas atmosphere is likely to occur periodically or occasionally in normal operation
Zone 2	an area in which an explosive gas atmosphere is not likely to occur in normal operation but, if it does occur, it will exist for a short period only
¹⁾ Definition according to EN 60079-10-1:2015	

As indicated by the upper flammable limit (UFL) for different gases according to Table 4 above, a certain minimum amount of air is required to be mixed with the flammable gas, to enable the gas to be ignited and burn, causing an explosion. Therefore, where air is not present at normal operating conditions inside closed systems for CH₂, CBG/CNG and LBG/LNG at fuelling stations, the flammable

gas inside such systems cannot ignite and cause an explosion in normal operation. However, the risk assessment of fuelling station systems should consider not only normal operating conditions, but also any conditions where air may be present in the system, for example:

- at starting up of a system
- after service and repair (e.g. exchange of compressors or sensors)

Also properties for gas used under non atmospheric conditions if applicable (e.g. pressurized or cooled gas), should be considered in the risk assessment. Depending on the minimum ignition energy, flammable substances are classified in equipment groups according to chapter 7.2.2.

Depending on the auto ignition temperature, flammable substances are classified in temperature classes according to chapter 7.2.2.

7.2.4.2 CH₂

Safety related to properties

CH₂ is considered as vehicle grade hydrogen gas designated as “hydrogen” or “CH₂” in the following. The safety aspects in the following relate to hydrogen gas under atmospheric conditions, unless otherwise stated or shown in the context.

Hydrogen has a wide flammability range according to Table 4, from 4 to 77 volume %. This range is much larger than the range for the other fuels in Table 4, and therefore poses a higher risk for the occurrence of explosive gas mixture when released. When ignited, the flame propagation characteristics such as flame speed (deflagration/detonation) and flame direction can be complex and vary depending on concentrations and containments. Flame speed of hydrogen-air mixture is higher than for LNG, LPG and petrol vapour. Such hydrogen mixtures are more sensitive to congestion and turbulence, potentially resulting in higher explosion over-pressure [6].

On the other hand, hydrogen gas at normal ambient temperatures has a much lower density relative to air, according to Table 4, which means it will rise up faster in air than the other gases. Furthermore, the low molecular mass for hydrogen entails a high diffusion coefficient, which also contributes to a faster dilution in air. I.e. the low density and high diffusion coefficient mean that the hydrogen is highly dispersive in air. However, the rapid mixing with air means also that an explosive mixture is created quickly considering the wide flammability range, before the hydrogen is diluted to a non-flammable mixture.

The density of hydrogen gas varies with temperature. For example, cold hydrogen vapour from spill of liquefied hydrogen in an area of normal ambient temperatures and pressure, may have a higher density than air, considering that hydrogen gas at boiling point (-253 °C) has a density of 1,3 kg/m³ [7] compared with 1,2 kg/m³ for air at +20 °C. This means that the cold hydrogen gas will spread out horizontally before it will rise up in air after being warmed up by the ground and air. Cold hydrogen gas may cause water vapour in the air to condensate, forming visible clouds where the cold hydrogen gas is present.

Liquid hydrogen evaporates quickly in normal atmosphere. The level of a liquid hydrogen pool decreases by 25-50 mm/min due to the evaporation. The evaporation of 1 litre liquid hydrogen yields roughly 50 liter of cold gas, which increases to about 830 litres when warmed up to normal ambient temperatures [6].

The lower flammability limit 4 % for hydrogen means that more hydrogen is required in a mixture with air to reach an explosive mixture, than is required for LPG (with a lower flammability limit of 2 %). In this sense hydrogen is safer than LPG.

Hydrogen is classified in equipment group IIC, with respect to the minimum ignition energy. Therefore, the spark energy required to ignite a mixture of hydrogen with air is very low and much lower than for the other fuels according to Table 4. In this sense hydrogen is less safe than the other fuels, with respect to for example spark energies in electrostatic discharges.

Hydrogen is classified in temperature class T1, with respect to the auto-ignition temperature. This is the same class or safer, than for the other fuels according to Table 4. In this sense hydrogen can be considered as being at least as safe as the other fuels.

Other characteristic safety aspects for hydrogen include [8]:

- Colourless, odourless (if not odorized), tasteless and non-toxic [7] (but is an asphyxiant)
- Nearly invisible flames in daylight and low infrared radiation
- Jets created by release from high pressure systems, create a loud jet if ignited

- Leaks easier through materials and seals than other gases due to the small hydrogen molecules
- Does not produce carbon monoxide when it burns (i.e. cannot cause fatalities caused by carbon monoxide poisoning)
- Hydrogen embrittlement which may cause loss of ductility for certain metallic and non-metallic materials (diffusion into metallic materials requires hydrogen gas molecules to dissociate into atoms)

If an effective ignition source is present close to the point of a starting release, the released hydrogen will be ignited if mixed with air in flammable concentrations. A flame or jet flame will occur. If such flames reach combustible materials and substances, this can cause a fire. In this case the main hazard is a fire and not an explosion. However, if the ignition source becomes ineffective and the fire is extinguished without the release being turned off, an explosion hazard can occur due to the formation of an explosive mixture of hydrogen with air caused by the release. The mixture may explode if an effective ignition source occurs or if the explosive mixture reaches an ignition source.

Therefore, it can be safer to allow burning hydrogen to burn until the release can be stopped, instead of extinguishing the burning hydrogen, depending on:

- combustible material and substances near the flames
- the risk for formation of explosive mixtures
- presence of effective ignition sources
- impact of an explosion

Furthermore, hydrogen flame, especially those emanating from high-pressure source, are extremely difficult to extinguish [7].

Standards reflecting best practice for CH₂ fuelling stations

In Sweden, the international technical specification ISO/TS 19880-1:2016 for gaseous hydrogen fuelling stations has been implemented as a national specification SIS-ISO/TS 19880-1:2016. The specification includes minimum design characteristics for safety of public and non-public fuelling stations, intended for light duty land vehicles (e.g. fuel cell electric vehicles).

In Norway, this ISO specification is not offered as a national specification by Standard Norge (www.standard.no). The situation seems to be the same in Denmark, where no national specification based on the ISO specification is offered by Dansk Standard (www.ds.dk). Also in Finland, this specification seems not to be offered, by Finnish Standards Association SFS (sales.sfs.fi).

In Germany, DIN Deutsches Institut für Normung (www.din.de) offers a draft standard DIN EN 17127:2017 (Gaseous hydrogen - Fueling stations - Part 1: General requirements). This draft German standard, is based on a draft European standard prEN 17127, which primarily addresses requirements relating to the interface between the fuelling station and the vehicle. EN 17127 is intended to focus principally on the content of ISO 19880-1 that influences interoperability with respect to this. ISO 19880-1 is currently on the way and intended to replace the technical specification ISO/TS 19880-1. EN 17127 is expected to be published early 2018 and ISO 19880-1 later in 2018, if positively received by ballot.

The safety and performance requirements for the entire hydrogen refuelling station (HRS), addressed in accordance with existing relevant European and National legislation, are not intended to be included in EN 17127. For guidance on considerations for entire hydrogen fuelling stations, the standard refers ISO/TS 19880-1 in a note.

Later on, it is likely that the European standardization organizations CEN and CENELEC, will publish a common European standard which is more or less based on the coming ISO standard ISO 19880-1

for gaseous hydrogen fuelling stations, including requirements related to safety for the entire stations. Such a standard will be adopted as national standard in all the actual countries (SE, NO, DK, FI and DE), as required by the CEN/CENELEC regulations. I.e. where will probably be a common best practice in place for the actual countries, based on such a standard, related to aspects covered by the standard.

Considering the situation above and pending a European standard, it is reasonable to assume that the technical specification ISO/TS 19880-1:2016 currently represents best common practice for the safety of the portion of a multifuel energy station which is used for hydrogen, for the actual countries. Therefore, Table 7 covers ISO/TS 19880-1:2016 as the only currently finalized international specification for such fuelling stations. The latest draft of the ongoing work on the standard ISO 19880-1, may provide complementary and useful information to the specification.

Other standards ISO currently is working on for gaseous hydrogen fuelling stations, include standards for dispensers, valves, compressors, hoses and fittings. Furthermore, a discussion is currently ongoing in ISO's and CEN/CENELEC's technical committees for hydrogen fuelling stations, to possibly start a standardization work on multifuel energy stations.

Table 7 - Specifications for CH₂ fuelling stations

Specification	Title
ISO/TS 19880-1:2016	Gaseous hydrogen – Fuelling stations – Part 1: General requirements
Note The cited editions were the latest editions at the time of writing this report.	

ISO/TS 19880-1:2016 requires hazardous areas (areas with potentially explosive atmospheres) to be classified according to the generic international standard IEC 60079-10-1. The corresponding generic European standard EN 60079-10-1, according to Table 5, is based on this international standard and is almost identical with it.

The specification ISO/TS 19880-1 itself, provides some additional considerations related to the classification of hazardous areas for hydrogen fuelling stations. For example, locations below the exhaust of ventilation of enclosures around hydrogen systems may not be considered as hazardous area, and no hazardous area need to be considered around the fuelling hose assembly, if certain requirements are fulfilled. Such considerations specific for hydrogen fuelling stations, contribute to a harmonized approach among countries who have adopted the specification ISO/TS 19880-1, facilitating the establishment of hydrogen fuelling station infrastructure in those countries.

ISO/TS 19880-1:2016 states that all electrical equipment in hazardous areas should be installed in accordance with the generic international standard IEC 60079-14, and should be inspected and maintained in accordance with IEC 60079-17. Service, repair, overhaul and reclamation should be according to IEC 60079-19.

The corresponding European standards EN 60079-14, EN 60079-17 and EN 60079-19, according to Table 5, are based on these international standards and are almost identical with them.

The corresponding national standards in the actual countries (SE, NO, DK, FI and DE), are based on the European standards mentioned above. Therefore, there is a set of standards for users in all these countries, which are based on common European standards and which to a high degree correspond also to the corresponding international IEC standards referred to in ISO/TS 19880-1. This facilitates the use of the same methods for classification of hazardous areas, installation, inspection,

maintenance, repair etc. However, as it is allowed on national level to add requirements and information to such European user standards, differences in methodology related to such national requirements and information may exist.

Example of other specifications for gaseous hydrogen stations, previously published in Europe, are:

- Handbook for Hydrogen Refuelling Station Approval, prepared in HyApproval project and published in 2008 [6]
- Code IGC Doc 15/06/E Gaseous Hydrogen Stations, prepared by the European Industrial Gases Association AISBL and published in 2006

Safety distances

ISO/TS 19880-1:2016 includes an informative annex (Annex A) with information about safety distances in some different countries. This information reveals relatively large variations in the requirements for safety distances, for different countries. Examples of safety distance requirements in Germany and Sweden are specified in

Table 8 (corresponding information for Denmark, Norway and Finland is missing in the standard). The table illustrates also different kind of safety distances, and examples of distances being regulated in one country but not in another country. The variations obviously make it difficult to establish multifuel energy stations in the same way in the different countries. Therefore, it is recommended to eliminate or reduce such differences for the safety distances, e.g. by regulating the distances in common European standards or directives.

To some extent, national provisions and standards may allow for reduction of certain stated safety distances based on risk assessment, the use of fire resistant walls, collision-proof obstacles etc. as applicable.

Table 8 - Example of safety distance requirements in Germany and Sweden according to ISO/TS 19880-1

Safety distance		Germany	Sweden
INSTALLATION LAYOUT DISTANCES <i>The installation lay-out distance is the minimum distance between the various units of the main equipment of the hydrogen installation required to prevent units causing damage to one another in case of incidents.</i>	Between Sub-Systems / Equipment of any kind	1 m Vessels without opening 0,5 m	1 m
PROTECTION DISTANCES <i>The protection distance is the minimum distance required between the installation/equipment to be protected of the possible source of an external hazard (e.g. a fire) to prevent damage.</i>	Presence of (liquid) combustibles above ground (like gasoline storage or tank truck)	5 m	50 m
	Private or public road (Collision by a vehicle, either present at the fuelling station or passing by a nearby road).		10 m
CLEARANCE DISTANCES <i>The clearance distance is the minimum distance between the potentially hazardous installation/equipment and the vulnerable targets within the fuelling station. Here, the hydrogen installation is regarded to be the source, while the surrounding people /objects are considered to be the targets.</i>	Gasoline storage	3 m	25 m
	LPG storage	8 m	25 m
	CNG hazardous elements		12 m
	Bulk liquid oxygen storage	5 m	12 m
	Building inside the plant		12 m
	Building of combustible material		12 m
	Building openings/windows/access doors		Same as for buildings in general
	Air intakes/ventilation	Out of hazardous area	Outside of hazardous area
EXTERNAL RISK ZONE <i>The external risk zone is the distance (or area) outside the fuelling station which has to be protected against hazards caused by the hydrogen installation. Here, the H2 installation (i.e. dangerous units thereof) is clearly the hazard source, while people and constructions offsite are regarded to be the target(s).</i>	Public Road		10 m (up to 50 km/h)
	Parking		6 m
	School/Hospital/ Place of public assembly/Other		100 m (exits from difficult to evacuate buildings)

Risk assessment

The specification ISO/TS 19880-1:2016 reflects best common practice according to the above. As described above, the specification covers minimum design characteristics for safety and, where appropriate, for performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty land vehicles.

The requirements according to ISO/TS 19880-1 can be considered as a result of a generic risk assessment, which does not necessitate further risk assessment to be performed if the fuelling station

complies with the requirements. However, the standard includes risk assessment as a flexible compliance option, to allow station owners and designers to flexibly define station-specific mitigations that achieve an equal or better level of safety to the requirements according to ISO/TS 19880-1. Such a risk assessment should be performed in accordance with ISO 31000, ISO/IEC 31010 and/or ISO 12100, using quantitative risk assessment (QAR) or semi-quantitative methods. Using QAR may for example allow for shorter safety distances and/or simplified station layout e.g. by using fire resistant barriers.

ISO 31000 describes principles and generic guidelines on risk management. ISO/IEC 31010 describes a range of different risk assessment techniques, with reference to other international standards describing such techniques in greater detail. Example of qualitative techniques which may be used as part of or as support to QAR:

- Hazard identification (HAZID)
- Hazard and operability study (HAZOP)
- Failure mode and effects analysis (FMEA)
- Fault tree analysis (FTA)
- Structured “What-if” technique (SWIFT)

ISO 12100 is a risk assessment standard for machinery, which specifies principles of risk assessment and risk reduction for achieving safety in the design of machinery.

Typical procedure for risk assessment is shown by the flow chart in Figure 1.

For risk assessment related to ignition hazards for the design of explosion protected equipment (equipment covered by the provisions in SE, NO, DK, FI and DE based on ATEX Directive 2014/34/EU), methodology according to harmonized standards according to chapter 7.2.6.4 should be used e.g. EN ISO 80079-36 and EN 15198 for non-electrical equipment.

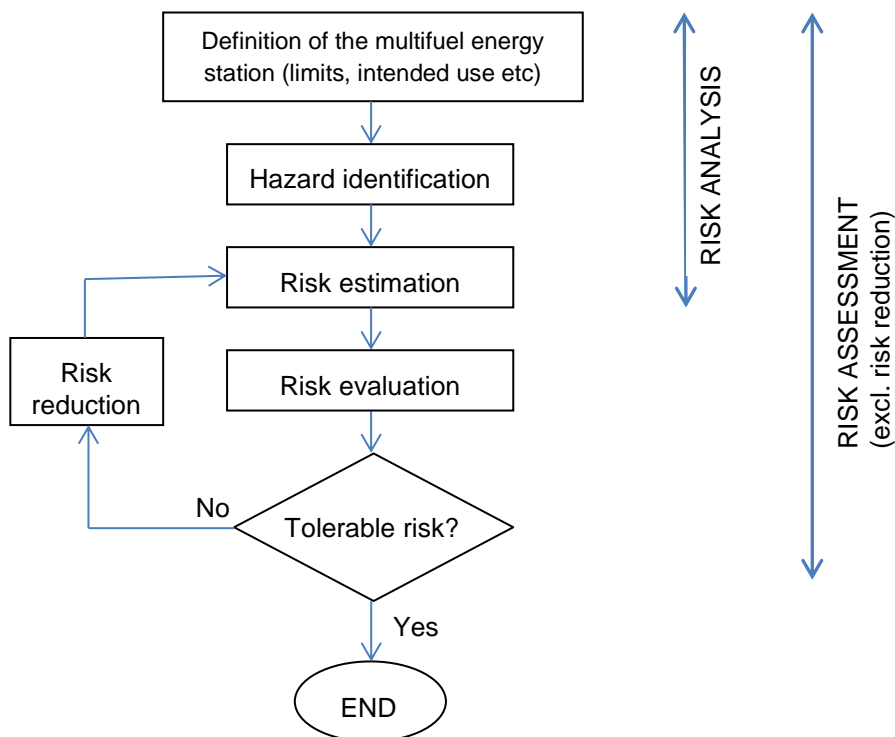


Figure 1 Risk assessment procedure

National differences and additional national requirements

While requirements for the design and verification of products are harmonized to large extent by product directives and regulations, in order to promote the free trade of products within EU and EEA, the practice for installation, use, maintenance, permit etc. is not harmonized to the same extent among the member states.

This means that there may be national differences or additional requirements related to such aspects, which may complicate for economic operators to establish and operate fuelling and multifuel energy stations in different countries. I.e. best practice for installation, use, maintenance etc. according to common implemented international standards, may not reflect all requirements which need to be considered nationally. Additionally, there are inspection, permit and notification procedures, which usually differ from country to country. Such procedures may relate to e.g. building permit, permit to handle flammable substances and pressure vessels.

Therefore, the establishment of fuelling and multifuel energy stations is facilitated by transparent information on any national requirements, beyond best practice according to national standards based on common international standards.

Case studies performed in 2012 [9, 7] of the establishment of hydrogen fuelling stations in Norway, showed how such establishments can be facilitated by increasing the operator's awareness and knowledge of the national differences and additional requirements.

In Sweden, there are currently no guidelines with transparent collected information on national requirements, beyond best practice according to the national specification SIS-ISO/TS 19880-1:2016, for hydrogen fuelling stations. However, there is such a guideline for methane gas stations (TSA 2015 "Filling stations for methane gas powered vehicles", according to chapter 7.2.4.3), with information which to a large extent is applicable also for hydrogen stations.

Preferably, national guidelines should provide information and requirements supplementary to best practice according to national standards which are based on common international standards. I.e. such complementary information is recommended to not duplicate or contradict with requirements in the national standard but may cover requirements according to national provisions which are not covered by the standard (e.g. required inspection and permit procedures, safety distances etc.). Such guidelines may also - in cooperation with the responsible national standardization organization - exemplify and clarify requirements in the standard.

Considering a coming national standard based on a coming European standard for gaseous hydrogen fuelling stations, for all the actual countries (SE, NO, DK, FI, DE), it is recommended to have national guidelines with supplementary information as described above, to facilitate the establishment and operation of fuelling and multifuel energy stations providing hydrogen.

For fuelling stations with conventional fuels (e.g. petrol, diesel and LPG), which are updated to a multifuel energy station to provide also clean fuels such as CH₂, CBG/CNG, LBG/LNG and/or BEV, national provisions and guidelines for conventional fuelling stations may include requirements which need to be considered for the expansion of such stations with clean fuels. Example of such national guidelines is the following handbook provided by the authority The Swedish Civil Contingencies Agency (MSB), in Sweden: "Hantering av brandfarliga gaser och vätskor på bensinstationer" ("Handling of flammable gases and liquids at petrol stations").

7.2.4.3 CBG/CNG

Safety related to properties

CBG/CNG is considered as vehicle grade methane gas designated as “vehicle gas” or “CBG/CNG” in the following (“fordonsgas” in Sweden). The safety aspects in the following relate to vehicle gas under atmospheric conditions, unless otherwise stated or shown in the context.

Note: The meaning of “vehicle gas” in this report should not be mixed with LPG, considering that “vehicle gas” in Germany is - or may be - understood as LPG.

Considering that vehicle gas to the dominant part consists of methane, it is reasonable to assume that safety-related data for these fuels can be represented by the data for methane according to Table 4. Comparing data for vehicle gas, with data for methane according to Table 4, confirms this assumption being reasonable. Complementary data for biogas and natural gas can be found in Table 16. This data fits reasonably well with the data for methane. Therefore, the following for vehicle gas, is based on data for methane according to Table 4.

Vehicle gas has a flammability range from approximately 4 to 17 volume %. This range is significantly more limited than the range for hydrogen, but wider than the range for petrol, propane and LPG. Therefore, in this sense, released vehicle gas poses a lower risk for the occurrence of explosive gas mixture than hydrogen. The broader range for vehicle gas - compared with the range for petrol, propane and LPG – may impose a higher risk for the occurrence of explosive gas. However, on the other hand, the lower flammability limit for petrol, propane and LPG ($LFL \leq 2$ volume %), indicates that the occurrence of explosive gas mixture from petrol, propane and LPG will be reached at a lower concentration than for vehicle gas.

The density of vehicle gas is approximately half of the density for air. Therefore, the vehicle gas tends to rise in air, but not as quickly as hydrogen which has a much lower density. Therefore, the safety cannot be based on the assumption that the vehicle gas will disappear quickly up in the air. This needs to be considered, especially if the temperature of released gas is significantly lower than the air temperature.

Furthermore, the diffusion coefficient for vehicle gas is higher than for petrol but much lower than for hydrogen, which means that the gas is not diluted as quickly in air as hydrogen.

Vehicle gas is classified in equipment group IIA, with respect to the minimum ignition energy. Therefore, the spark energy required to ignite a mixture of vehicle gas with air, is higher than for hydrogen and ethanol according to Table 4. In this sense vehicle gas is safer than hydrogen and ethanol, but equal to the other fuels in Table 4.

Vehicle gas is classified in temperature class T1, with respect to the auto-ignition temperature. This is the same class or safer, than for the other fuels according to Table 4. In this sense vehicle gas can be considered as being at least as safe as the other fuels.

Vehicle gas is colourless and odourless (if not odorized). For CBG/CNG stations using LNG as an onsite source, properties and measures for LNG according to chapter 7.2.4.4 need to be considered.

If an effective ignition source is present close to the point of a starting release, the released vehicle gas will be ignited if mixed with air in flammable concentrations. A flame or jet flame will occur. If such flames reach combustible materials and substances, this can cause a fire. In this case the main hazard is a fire and not an explosion. However, if the ignition source becomes ineffective and the fire is extinguished without the release being turned off, an explosion hazard can occur due to the formation of an explosive mixture of vehicle gas with air caused by the release. The mixture may explode if an effective ignition source occurs or if the explosive mixture reaches an ignition source.

Therefore, it can be safer to allow burning vehicle gas to burn until the release can be stopped, instead of extinguishing the burning hydrogen, depending on:

- combustible material and substances near the flames
- the risk for formation of explosive mixtures
- presence of effective ignition sources
- impact of an explosion

Standards reflecting best practice for CBG/CNG fuelling stations

In order to support the Directive 2014/94/EU related to the deployment of alternative fuels infrastructure, issued by European Parliament and the Council of the European Union, the European Commission has requested the European standardization organization CEN to transfer the international standard ISO 16923:2016 to an European standard, if possible.

A European standard based on the international standard ISO 16923:2017, is currently on the way. A draft (prEN ISO 16923) is under enquiry and planned to be voted on in 2018.

In Sweden, the international standard ISO 16923:2016 for natural gas fuelling stations has been implemented on voluntary basis as a national standard SS-ISO 16923:2017. The standard covers design, construction, operation, inspection and maintenance of CNG stations for vehicles.

In Norway, ISO 16923:2017 has not been implemented as a national standard, by Standard Norge (www.standard.no). The same applies in Denmark, where Dansk Standard (www.ds.dk) offers the draft European standard prEN ISO 16923 as DSF/prEN ISO 16923. The same applies also in Finland, where Finnish Standards Association SFS (sales.sfs.fi) does not offer a national standard based on ISO 16923:2016.

As in Denmark, Germany - DIN Deutsches Institut für Normung (www.din.de) - does not offer a national standard based on ISO 16923:2016, but offers the draft European standard prEN ISO 16923 as draft standard DIN EN ISO 16923.

This means that best practice for CNG stations for fuelling vehicles, based on ISO 16923:2016, probably will be implemented as national standard late 2018 or in 2019, in all the actual countries (SE, NO, DK, FI and DE) as required by the CEN/CENELEC regulations. I.e. where will probably be a common best practice in place for the actual countries, based on such a standard, related to aspects covered by this standard, in 2019 at latest.

Considering the situation above and pending EN ISO 16923, it is reasonable to assume that the draft standard prEN ISO 16923 and ISO 16923:2016 currently represents best common practice for the portion of a multifuel energy station used for vehicle gas, in the actual countries. Table 9 below, covers ISO 16923:2016 as the only currently finalized international standard for CNG fuelling stations and the corresponding European draft standard.

Table 9 - Standards for CNG fuelling stations

Standard	Title
ISO 16923:2016	Natural gas fuelling stations – CNG stations for fuelling vehicles
prEN ISO 16923 (2017)	Natural gas fuelling stations – CNG stations for fuelling vehicles
Note	
The cited editions were the latest editions at the time of writing this report.	

The standard refers to generic standards in the IEC 60079 series, for the protection from ignition in explosive atmospheres. For hazardous area classification and for ventilation, it refers to the generic standard IEC 60079-10-1. The standard does not allow areas classified as hazardous for a compressor, to extend beyond the station property line. The standard itself includes a number of examples on classification of hazardous areas for a CNG station, in an informative Annex (Annex A). Such examples facilitate the design and establishment of fuelling and multifuel energy stations which provides vehicle gas.

The standard requires electrical equipment associated with compressors and buffer storages, to be suitable for the zone in which the equipment is installed and refers to the generic user standard: IEC 60079-14.

The standard does not forbid indoor fuelling, but have a note informing that indoor fuelling is not allowed in some countries. Permanently occupied areas are not allowed above the fuelling building, according to the standard.

There is another standard-related natural gas vehicle operation:
EN 13423:2000 Compressed natural gas vehicle operations

This standard gives recommendations for drivers of natural gas vehicles and workshop operations.

The standard is mainly directed to:

- vehicle park owners/operators/users
- natural gas vehicle dealers/owners/users
- workshop operators

This standard has been implemented as national standard in all the actual countries (SE, NO, DK, FI and DE), as required by the CEN/CENELEC regulations. I.e. there is a common best practice for all the actual countries, related to aspects covered by this standard.

For CBG/CNG stations using LBG or LNG as an onsite source (i.e. LCNG fuelling stations), see chapter 7.2.4.4 for best practice and standards to be considered for the portion of the fuelling station which handles LBG/LNG.

Safety distances

The standard ISO 16923:2017 uses the term "separation distance" instead of the term "safety distance", where separation distances is the minimum separation between a hazard source and an object which may be affected by the hazard.

ISO 16923 does not present different national requirements on separation distances, as done in an informative Annex in ISO/TS 19880-1 for hydrogen fuelling stations. However, it presents requirements on separation distances, in a normative Annex (Annex B), which shall be fulfilled to comply with the standard. Such clear requirements on safety distances facilitate the design and the establishment of fuelling and multifuel energy stations which provides CNG.

For separation distances to objects located outside the boundaries of the fuelling station, the standard requires the distances to not exceed the distances which apply for liquid fuels. For distances to certain objects inside the boundaries e.g. building openings, the standard specifies distances to dispensers and to storage cylinders and compressor. For CBG/CNG stations using LBG or LNG as an onsite source (i.e. LCNG fuelling stations), see chapter 7.2.4.4 for safety distances to be considered for the portion of the fuelling station which handles LBG/LNG.

Risk assessment

The standard ISO 16923:2016 (and the corresponding European draft prEN ISO 16923, 2017) reflects best common practice according to the above. As described above, the standard covers design, construction, operation, inspection and maintenance of CNG stations for vehicles.

Risk assessment shall follow the techniques described in ISO 12100 for assessment of machinery safety and ISO/IEC 31010 for general site risk management, or local applicable standards. The assessment shall include design, construction, operation and maintenance of the CNG fuelling station. Measures to reduce explosion risks and fire shall be applied. Protection from ignition in zones with explosive atmosphere, shall comply with the generic IEC 60079 series of standards.

ISO 12100 is a risk assessment standard for machinery, which specifies principles of risk assessment and risk reduction for achieving safety in the design of machinery.

ISO/IEC 31010 describes a range of different risk assessment techniques, with reference to other international standards describing such techniques in greater detail. Examples of qualitative techniques are:

- Hazard identification (HAZID)
- Hazard and operability study (HAZOP)
- Failure mode and effects analysis (FMEA)
- Fault tree analysis (FTA)
- Structured “What-if” technique (SWIFT)

Such qualitative techniques can be used as part of or as support to quantitative risk assessment (QAR). Typical procedure for risk assessment is shown by the flow chart in Figure 1.

For risk assessment related to ignition hazards for the design of explosion protected equipment (equipment covered by the provisions in SE, NO, DK, FI and DE based on ATEX Directive 2014/34/EU), methodology according to harmonized standards according to chapter 7.2.6.4 should be used e.g. EN ISO 80079-36 and EN 15198 for non-electrical equipment.

National differences and additional national requirements

While requirements for the design and verification of products are harmonized to large extent by product directives and regulations, in order to promote the free trade of products within EU and EEA, the practice for installation, use, maintenance, permit etc. is not harmonized to the same extent among the member states.

This means that there may be national differences or additional requirements related to such aspects, which may complicate for economic operators to establish and operate fuelling and multifuel energy stations in different countries. I.e. best practice for installation, use, maintenance etc. according to common implemented international standards, may not reflect all requirements which need to be considered nationally. Additionally, there are inspection, permit and notification procedures, which usually differ from country to country. Such procedures may relate to e.g. building permit, permit to handle flammable substances and pressure vessels.

Therefore, the establishment of fuelling and multifuel energy stations is facilitated by transparent collected information on national requirements, beyond best practice according to national standards based on common international standards. An example of such information, contained in a national guideline in Sweden, is TSA 2015 “Filling stations for methane gas powered vehicles” issued by the association Energigas Sverige.

TSA 2015 covers the design, inspection, operation and maintenance of filling stations for methane gas powered vehicles, including requirements on safety distances. The code is designed to provide a safe installation in compliance with Swedish legislation. Similar guidelines issued by authorities and/or associations, might be found in other countries.

Another Swedish guideline is “Hantering av brandfarliga gaser och vätskor på bensinstationer” (Handling of flammable gases and liquids at petrol stations), which applies for petrol stations, but which also contains requirements related to CBG (e.g. requirements related to safety distances). This guideline is provided by the Swedish authority: The Swedish Civil Contingencies Agency (MSB).

Considering the implementation of SS-ISO 16923 as national standard in Sweden 2017 - which covers design, construction, operation and maintenance of CNG stations for vehicles - there might be a need to match national guidelines with this standard.

Preferably, national guidelines should provide information and requirements supplementary to best practice according to national standards which are based on common international standards. I.e. such complementary information is recommended to not duplicate or contradict with requirements in the national standard but may cover requirements according to national provisions which are not covered by the standard (e.g. required inspection and permit procedures, safety distances etc.). Such guidelines may also - in cooperation with the responsible national standardization organization - exemplify and clarify requirements in the standard.

Considering national standards on the way (based on the coming European standard EN ISO 16923) for all the actual countries (SE, NO, DK, FI, DE), it is recommended to have national guidelines with supplementary information as described above, to facilitate the establishment and operation of fuelling and multifuel energy stations providing vehicle gas.

For fuelling stations with conventional fuels (e.g. petrol, diesel and LPG), which are updated to a multifuel energy station to provide also clean fuels such as CH₂, CBG/CNG, LBG/LNG and/or BEV, national provisions and guidelines for conventional fuelling stations may include requirements which need to be considered for the expansion of such stations with clean fuels. Example of such national guidelines is the following handbook provided by the authority The Swedish Civil Contingencies Agency (MSB), in Sweden:

“Hantering av brandfarliga gaser och vätskor på bensinstationer” (“Handling of flammable gases and liquids at petrol stations”).

For CBG/CNG stations using LBG or LNG as an onsite source (i.e. LCNG fuelling stations), see chapter 7.2.4.4 for national differences and additional national requirements to be considered, for the portion of the fuelling station which handles LBG/LNG.

7.2.4.4 LBG/LNG

Safety related to properties

Liquefied bio or natural gas is combustible, but the liquid is not explosive in itself, unless possibly distributed in air in small droplets forming mist. Therefore, of primary interest for explosion risks, is the vapour or gas which can be released from the liquefied gas. For the gas phase, the properties and safety aspects relevant for the vehicle gas (CBG/CNG) according to chapter 7.2.4.3, applies. The gas is designated “vehicle gas” or “CBG/CNG” in the following. The safety aspects in the following relate to vehicle gas under atmospheric conditions, unless otherwise stated or shown in the context.

Liquefied vehicle gas is clear, colourless and odourless. To transfer vehicle gas from the gas phase to liquid phase requires cooling the gas to at least -160 °C. The density of liquefied vehicle gas is approximately half of that for water. Therefore, it will float on water if it is spilled out where water is present.

There are some main differences between the gas and liquefied gas (LBG/LNG), which need to be considered for explosion risks;

- The source of gas release for CBG/CNG is normally attributable to leaks or openings in walls and structures that enclose pressurized gas. The source of gas release for LBG/LNG can be such leaks or openings in walls and structures, located above the level of enclosed liquefied gas. The source of release can also be such leaks or openings in walls and structures where liquid is located, causing liquid to be released to an ambient with atmospheric conditions, where the released liquid will act as a source of release of vehicle gas when the liquid is vaporized to gas due to the atmospheric conditions.
- The liquefied gas is normally cold. Therefore, gas released from the liquefied gas is also cold before it is warmed up by the ambient. Cold gas has a higher density than warm gas. Cold vehicle gas may have a density which exceeds the density of air, considering that methane gas at boiling point (-161 °C) has a density of 1,8 kg/m³ [7] compared with 1,2 kg/m³ for air at +20 °C. Release of pressurized gas, contributes also to the cooling of the gas when the compressed gas expands under atmospheric conditions.

The initial density of cold vehicle gas (in gas phase), before it is warmed up by the ground or ambient, will cause the gas to not rise upwards initially. These effects along with possible surfaces, ground and underground parts which may be exposed to the released liquid (including any underground wells, ducts etc. that the liquid can drain into and accumulate), need to be considered for the classification of hazardous areas and the installations.

The low temperature of liquefied vehicle gas may cause low temperatures on parts of the installations which may cause injuries on persons if touched on. Therefore, personnel should not touch such parts and they should wear protective clothing. Expansion, contraction and mechanical stress of the installation, caused by large temperature changes or differences e.g. between the low temperature for liquefied gas and the ambient temperature, need to be considered in order to not cause break downs or leakages. Materials need to have properties matching the temperatures, pressures, adjoining materials and the gas.

Gas generated by cold liquefied vehicle gas in enclosed systems, when heated up by the ambient, needs appropriate space in such systems. Such enclosed systems need safety valves for pressure relief of excessive pressure, if the gas is not safely converted back to liquefied gas.

In case of liquid spill, the flow should be stopped (e.g. by closing valves further up streams if possible). The area near it should be evacuated until the liquid has evaporated, the gas has dispersed and the gas concentrations are below the lower flammability limit.

Standards reflecting best practice for LBG/LNG fuelling stations

In order to support the Directive 2014/94/EU related to the deployment of alternative fuels infrastructure, issued by European Parliament and the Council of the European Union, the European Commission has requested the European standardization organization CEN to transfer the international standard ISO 16924:2016 to an European standard, if possible.

A European standard based on the international standard ISO 16924:2016, is currently on the way. A draft (prEN ISO 16924) is under enquiry and planned to be voted on in 2018.

In Sweden, the international standard ISO 16924:2016 for natural gas fuelling stations has been implemented on voluntary basis as a national standard SS-ISO 16924:2016. The standard covers design, construction, operation, maintenance and inspection of LNG stations for vehicles.

In Norway, ISO 16924:2017 has not been implemented as a national standard, by Standard Norge (www.standard.no). The same applies in Denmark, where Dansk Standard (www.ds.dk) offers the draft European standard prEN ISO 16924 as DSF/prEN ISO 16924. The same applies also in Finland, where Finnish Standards Association SFS (sales.sfs.fi) does not offer a national standard based on ISO 16924:2016.

As in Denmark, Germany - DIN Deutsches Institut für Normung (www.din.de) - does not offer a national standard based on ISO 16924:2016, but offers the draft European standard prEN ISO 16924 as draft standard DIN EN ISO 16924.

This means that best practice for LNG stations for fuelling vehicles, based on ISO 16924:2016, probably will be implemented as national standard late 2018 or in 2019, in all the actual countries (SE, NO, DK, FI and DE) as required by the CEN/CENELEC regulations. I.e. where will probably be a common best practice in place for the actual countries, based on such a standard, related to aspects covered by this standard, in 2019 at latest.

Considering the situation above and pending EN ISO 16924, it is reasonable to assume that the draft standard prEN ISO 16924 and ISO 16924:2016 currently represents best common practice for the portion of a multifuel energy station used for LBG/LNG, in the actual countries. Table 10 below, covers ISO 16924:2016 as the only currently finalized international standard for CNG fuelling stations, and also the corresponding European draft standard.

Table 10 - Standards for LNG fuelling stations

Standard	Title
ISO 16924:2016	Natural gas fuelling stations – LNG stations for fuelling vehicles
prEN ISO 16924 (2017)	Natural gas fuelling stations – LNG stations for fuelling vehicles
Note	
The cited editions were the latest editions at the time of writing this report.	

The standard refers to generic standards in the IEC 60079 series, for the protection from ignition in explosive atmospheres. For hazardous area classification, it refers to the generic standard IEC 60079-10-1. The standard does not allow areas classified as hazardous, to extend beyond the boundaries of the station, unless a complementary risk assessment is carried out. The standard itself includes a number of examples on classification of hazardous areas for a LNG station, in an informative Annex (Annex A). Such examples facilitate the design and establishment of fuelling and multifuel energy stations which provides LBG/LNG.

The standard requires electrical and non-electrical equipment and components used in hazardous areas, to be designed for the area and to conform to the requirements according to IEC 60079. The installation of electrical equipment, wiring and cables, shall comply with IEC 60079-14 and other relevant parts of IEC 60079.

Inspection, testing and maintenance of electrical equipment and installations, shall comply with IEC 60079-17.

For parts of a LNG station handling CNG, the standard ISO 16924:2016 refers to requirements according to the standard ISO 16923:2016 described in chapter 7.2.4.3.

Safety distances

The standard ISO 16924:2017 uses the term "separation distance" instead of the term "safety distance", where separation distances is the minimum separation between a hazard source and an object which may be affected by the hazard.

ISO 16924 does not present different national requirements on separation distances, as done in an informative Annex in ISO/TS 19880-1 for hydrogen fuelling stations. However, it presents requirements on separation distances in a normative Annex (Annex B), which shall be fulfilled to comply with the standard. Such clear requirements on safety distances facilitate the design and the establishment of fuelling and multifuel energy stations which provides LNG.

The standard specifies separation distances between a number of objects, for example:

- between buildings and components containing LNG
- between buildings and offload connections
- fuelling vehicle and LNG tank
- station boundary limit and offload connections

For parts of a LNG station handling CNG, the standard ISO 16924:2016 refers to requirements according to the standard ISO 16923:2016 described in chapter 7.2.4.3.

Risk assessment

The standard ISO 16924:2016 (and the corresponding European draft prEN ISO 16924, 2017) reflects best common practice according to the above. As described above, the standard covers design, construction, operation, maintenance and inspection of LNG stations for vehicles.

Risks shall be managed throughout the life cycle of the LNG fuelling station. The risks shall be systematically identified, analysed and evaluated. The principles and guidelines of ISO 12100, ISO 31000 and ISO/IEC 31010 shall be followed in developing a risk management policy and framework.

Risk assessment shall follow one or more of the techniques described in ISO/IEC 31010, to reduce the risks to as low as reasonably practicable, by implementing appropriate mitigation measures.

ISO 12100 is a risk assessment standard for machinery, which specifies principles of risk assessment and risk reduction for achieving safety in the design of machinery.

ISO 31000 describes principles and generic guidelines on risk management. ISO/IEC 31010 describes a range of different risk assessment techniques, with reference to other international standards describing such techniques in greater detail. Examples of qualitative techniques are:

- Hazard identification (HAZID)
- Hazard and operability study (HAZOP)
- Failure mode and effects analysis (FMEA)
- Fault tree analysis (FTA)
- Structured “What-if” technique (SWIFT)

Such qualitative techniques can be used as part of or as support to quantitative risk assessment (QAR). Typical procedure for risk assessment is shown by the flow chart in Figure 1.

For risk assessment related to ignition hazards for the design of explosion protected equipment (equipment covered by the provisions in SE, NO, DK, FI and DE based on ATEX Directive 2014/34/EU), methodology according to harmonized standards according to chapter 7.2.6.4 should be used e.g. EN ISO 80079-36 and EN 15198 for non-electrical equipment.

National differences and additional national requirements

While requirements for the design and verification of products are harmonized to large extent by product directives and regulations, in order to promote the free trade of products within EU and EEA, the practice for installation, use, maintenance, permit etc. is not harmonized to the same extent among the member states.

This means that there may be national differences or additional requirements related to such aspects, which may complicate for economic operators to establish and operate fuelling and multifuel energy stations in different countries. I.e. best practice for installation, use, maintenance etc. according to common implemented international standards, may not reflect all requirements which need to be considered nationally. Additionally, there are inspection, permit and notification procedures, which usually differ from country to country. Such procedures may relate to e.g. building permit, permit to handle flammable substances and pressure vessels.

Therefore, the establishment of fuelling and multifuel energy stations is facilitated by transparent collected information on national requirements, beyond best practice according to national standards based on common international standards.

In Sweden, there are currently no guidelines with transparent collected information on national requirements, beyond best practice according to the national standard SS-ISO 16924:2016, for LNG fuelling stations. However, there is such a guideline for methane gas stations (TSA 2015 “Filling stations for methane gas powered vehicles”, according to chapter 7.2.4.3), with information which is applicable to large extent also for LNG, and especially for parts of a LNG station which handles CNG.

Preferably, national guidelines should provide information and requirements supplementary to best practice according to national standards which are based on common international standards. I.e. such complementary information is recommended to not duplicate or contradict with requirements in the national standard, but may cover requirements according to national provisions which are not covered by the standard (e.g. required inspection and permit procedures, safety distances etc.). Such guidelines may also - in cooperation with the responsible national standardization organization - exemplify and clarify requirements in the standard.

Considering national standards on the way (based on the coming European standard EN ISO 16924) for all the actual countries (SE, NO, DK, FI and DE), it is recommended to have national guidelines

with supplementary information as described above, to facilitate the establishment and operation of fuelling and multifuel energy stations providing LBG/LNG.

For fuelling stations with conventional fuels (e.g. petrol, diesel and LPG), which are updated to a multifuel energy station to provide also clean fuels such as CH₂, CBG/CNG, LBG/LNG and/or BEV, national provisions and guidelines for conventional fuelling stations may include requirements which need to be considered for the expansion with clean fuels. An example of such national guidelines is the following handbook provided by the authority The Swedish Civil Contingencies Agency (MSB), in Sweden:

“Hantering av brandfarliga gaser och vätskor på bensinstationer” (“Handling of flammable gases and liquids at petrol stations”).

For parts of a LNG station handling CNG, the standard ISO 16924:2016 refers to requirements according to the standard ISO 16923:2016 described in chapter 7.2.4.3.

For LBG/LNG stations handling CBG or CNG in parts of the fuelling station, see chapter 7.2.4.3 for national differences and additional national requirements to be considered for the portion of the fuelling station which handles CBG/CNG.

7.2.4.5 Electrical charging of vehicles

Background

Charging batteries of battery electric vehicles (BEVs) is another desirable energy supply option which can be provided by a multifuel energy station. Therefore, it is of interest for a multifuel energy station to consider the compatibility for such an option, with providing other clean or conventional fuels, with respect to safety aspects related to explosion risks.

Explosion risks and best practice related to charging facilities and charging of BEVs

Charging stations are normally not explosion protected and may therefore cause ignition of gas or vapour from fuels mixed with air, which may cause explosions. Therefore, charging facilities need to locate, and charging shall be done, outside the hazardous area, in line with the general principles for integrated explosion safety according to chapter 7.2.3. This is also in line with avoiding vehicles (with potential ignition sources) to be in hazardous areas.

In case spill zones (e.g. where the vehicles are parked when filled with liquid fuels at dispensers or when unloading liquid fuels from tankers) are not included in hazardous areas, charging facilities and charging should be avoided on such places as well.

Charging stations are electrical equipment with ignition sources according to chapter 7.2.3. Typical ignition sources for such electrical equipment are sparks caused by short circuits and breaks in electrical circuits, and possibly high surface temperatures caused by electric power. The short circuits and breaks can be intentional (as for switches, disconnectors and contactors) or can be unintentional due to faults and abnormal conditions. For example, when disconnecting the charger from the BEV, a spark will occur at the point of disconnection if the charging circuit carries current when broken. Such a spark can be capable of igniting an explosive gas mixture. Roughly, the spark energy is proportional to the current in square which means that breaking high currents, as provided by fast charges, may produce significantly higher spark energies than breaking lower charging currents.

Other aspects to be considered for the location of charging places, on a multifuel energy station include;

- Avoid places on low ground points, where liquid fuels or liquefied gas may accumulate upon a release
- Avoid places with underground sewages, drainage canals, wells and the like, where liquid fuels or liquefied gas may flow or accumulate upon a release
- Avoid places close to access and exit roads for tankers and trailers supplying the station with fuel
- In case of fire hazard due to high charging currents at unattended fast charging, and if such fires would affect installations containing fuels where identified by a risk assessment, means should be provided to detect such fires at the charging facility.

In case of emergency shutdown of fuelling equipment caused by abnormal release of fuels (e.g. upon detection of high gas concentrations), the power supply to charging stations located at multifuel energy stations should be automatically disconnected if the charging station is located such that it can be exposed to the fuel or released gas.

The location of charging stations outside hazardous areas is normally feasible, considering the limited hazardous areas at a fuelling station. Hazardous areas surrounding compressor housings, storages, ancillaries and dispensers on a CNG station, are typically within 0,2–10 m for a CNG fuelling station

according to ISO 16923:2017, Annex A, with the possibility of applying reduced zones based on protection methods according to IEC 60079-10-1.

As charging stations shall be installed outside hazardous areas, such installation can be done according to the national code of practice in the actual countries (SE, NO, DK, Fi and DE) applicable for installation of ordinary location equipment. I.e. installation according to codes of practices based on EN 60079-14, for installations in hazardous area, need not to be complied with, except for any cables passing through hazardous areas. The charging stations and their connections to vehicles shall be designed for the intended use considering the current, frequency and duration of the intended charging. For fast charging facilities, the fusing and capacity of the local transformer station may need to be considered and limit the number of possible fast charging points on a multifuel energy station.

7.2.5 Concept for a multifuel energy station – Safety aspects to be considered

7.2.5.1 Coordination with respect to potential incompatibilities

For a multifuel energy station, the combination of fuels with different properties according to chapter 7.2.4 above, can involve some challenges with respect to the safety related to explosion risks. However, such challenges can normally be solved by thoughtful decisions based on good knowledge and competence. An important part in best practice for multifuel energy stations is to coordinate the needs for different fuels in a way which is safe and minimizes the cost for such stations. Examples of such considerations can be found in Table 11. The table gives examples of measures to be considered in order to meet the needs of different types of fuels, based on the properties for different fuels described above. The table includes also example of measures to be considered for stations which provide petrol with a need to also be able to offer ethanol.

Table 11 - Examples of coordination related to the use of multiple fuels in multifuel energy stations

Example of potential incompatibility	Coordinating measures to eliminate the incompatibility
Hazardous areas may have different equipment groups (explosion groups), due to different fuels.	For explosion protected equipment to be used in areas with different equipment groups (e.g. portable equipment, or stationary equipment located in areas with overlapping hazardous areas related to different fuels), select equipment which fulfils the most severe of the actual equipment groups for the hazardous areas. Example Select equipment with equipment group IIC for a fuelling station which provides bio gas and natural gas (equipment group IIA), and which also provide hydrogen (equipment group IIC).
Hazardous areas may have different temperature classes, due to different fuels.	For explosion protected equipment to be used in areas with different temperature classes (e.g. portable equipment, or stationary equipment located in areas with overlapping hazardous areas related to different fuels), select equipment which fulfils the most severe of the actual temperature classes for the hazardous areas. Example Select equipment with equipment group T3 for a fuelling station which provides LPG (temperature class T2), Hydrogen (temperature class T1), and which also provides petrol (temperature class T3).
Hazardous areas caused by releases from different fuels, causing different zones.	For explosion protected equipment to be used in areas with different zones (e.g. portable equipment, or stationary equipment located in areas with overlapping different zones related to different fuels), select equipment which fulfils the most severe of the actual zones. Example Select equipment suitable for zone 1 (category 2 according to ATEX Directive 2014/34/EU), if the equipment in zone 2 (e.g. a part of CNG dispenser in zone 2 caused by the CNG) is exposed also to zone 1 emanating from another nearby source of release from another fuel.
Different design requirements apply for the explosion protection of dispensers which provide different gaseous fuels, depending on fuels intended to be used, with respect to e.g. equipment group (explosion group) and temperature class.	For multifuel dispensers, consider the most severe design requirements related to the different fuels to be used e.g. the most severe equipment group and temperature class for the fuels. Example For components and equipment in a multifuel dispenser designed to provide CBG/CNG (IIA, T1), CH2 (IIC, T1) and LPG (IIA, T2), select

	components and equipment which fulfils the requirements for equipment group IIC and temperature class T2 as appropriate.
Explosion protected electrical equipment are designed for use in certain ambient temperature ranges. The lower temperature limit for these ranges may be incompatible with the temperature they might be exposed to from cold LBG/LNG.	For explosion protected equipment exposed to low temperatures caused by cold LBG/LNG, select equipment which is rated for the low temperature.
Dispensers and other equipment for petrol with equipment group IIA, does not meet the need for ethanol with equipment group IIB, if updating the facility to provide ethanol.	For a multifuel energy station providing petrol, but with the possibility to update the facility to provide ethanol; Select explosion protected dispensers and other equipment to not only suit petrol with equipment group IIA, but to also suit ethanol with equipment group IIB.
Ventilation pipes from tanks for liquid ethanol fuels may require end of line flame arrestors, while such arrestors might not be required for petrol tanks.	For a multifuel energy station providing petrol, but with the possibility to update the facility to provide also ethanol; Use end of line flame arrestors suitable for ethanol for all tanks, to allow flexible usage of storage tanks for both ethanol and petrol.

Another possible co-ordination advantage for a multifuel energy station, is that the recurring inspections of the electrical installations and maintenance (e.g. according to EN 60079-17, EN 60079-29-2, ISO 16923 and ISO 16924 as applicable), can be coordinated more efficiently for a multifuel energy station located on one place, instead of for multiple stations with different fuels located on different places.

Example of coordination aspects related to climatic conditions for the actual countries (SE, NO, DK, FI and DE) due to their location in the northern part of Europe, to be considered for safe installation and use of equipment according to EN 60079-14:

- For safety-related equipment intended to be installed or used outdoor, use equipment rated for the low local ambient temperatures which may occur winter time (e.g. -40 °C in northern part of Sweden)
- Consider an increased risk for build-up of electrostatic charges due to a low humidity in the air at low ambient temperatures winter time

Another coordination aspect to consider for the use of liquefied gas fuels is related to the low temperature which may occur on parts of a multifuel energy station which processes such fuels. Explosion protected equipment exposed to such low temperatures, need to be rated accordingly.

Normally, there are good possibilities to use facilities for electrical charging of vehicles on multifuel energy stations, considering aspects according to chapter 7.2.4.5. Charging stations shall be installed outside hazardous areas and such areas have normally limited extent, according to chapter 7.2.4.5. Furthermore, codes of practice for installations in hazardous areas need not to be considered for such installations. Installation can be made according to code of practice for installation of ordinary location equipment such as charging stations for public use on public places other than fuelling stations.

7.2.5.2 Standards reflecting best practice for multifuel energy stations

Best practice for multifuel energy stations based on common specifications and standards for the actual countries (SE, NO, DK, FI and DE), is represented by the best practice and standards applicable for each clean fuel according to chapter 7.2.4, compiled in Table 12.

I.e. for each portion of a multifuel energy station handling a specific clean fuel, best practice is represented by the corresponding standard/specification according to Table 12, and for electrical charging of vehicles with batteries aspects according to chapter 7.2.4.5 should be considered.

Table 12 - Common standards/specifications for fuelling stations providing clean fuels

Fuel	Standard/specification	Title
CH2	ISO/TS 19880-1:2016	Gaseous hydrogen – Fuelling stations – Part 1: General requirements
CBG/CNG	ISO 16923:2016 prEN ISO 16923 (2017)	Natural gas fuelling stations – CNG stations for fuelling vehicles
LBG/LNG	ISO 16924:2016 prEN ISO 16924 (2017)	Natural gas fuelling stations – LNG stations for fuelling vehicles
Note The cited editions were the latest editions at the time of writing this report.		

For explosion risks, the ISO standards refer to high extent to other generic international standards (IEC 60079 and ISO 80079 series of standards). Corresponding generic European standards are based on these generic international standards and they are identical or almost identical with the international standards. The generic European standards related to explosion protection, has been implemented as national standards in the actual countries (SE, NO, DK, FI and DE). Therefore, the requirements in the actual countries related to explosion risks for equipment in general, are well harmonized i.e. the requirements related to explosion protection are the same or almost the same in the actual countries.

The standards/specifications according to Table 12 do not only cover best practice for the design, construction, operation, maintenance and inspection related to explosion risks. They do also cover design, construction, operation, maintenance and inspection related to other risks e.g. hazards related to pressurized equipment and related to fire.

Beyond the common best practice and standards for clean fuels according to the above, provisions, practice and standards for conventional fuels (e.g. petrol, diesel and LPG) need to be considered also, for multifuel energy stations which provide conventional fuels. Considering that existing fuelling stations which provide conventional fuels may be expanded to provide also clean fuels. As the conventional fuels have been on the market for a quite long time, there is generally a well-developed regulatory framework and standards in place for fuelling stations related to these fuels in the actual countries (SE, NO, DK, FI and DE). Provisions and standards for conventional fuels may for example require certain safety distances to be kept between parts of a station containing conventional liquid fuels and other parts containing clean gas fuels.

Example of national guidelines for petrol fuelling stations is the following handbook provided by the authority The Swedish Civil Contingencies Agency (MSB), in Sweden: “Hantering av brandfarliga gaser och vätskor på bensinstationer” (“Handling of flammable gases and liquids at petrol stations”). These guidelines address design, inspection, operation, maintenance and permit procedures for petrol

stations. They do also address requirements related to CBG/LNG and ethanol, for example distance requirements between storage of and dispensers for clean gas, and other parts of the fuelling station.

Similar guidelines issued by authorities and/or associations, might be found in the other actual countries.

As the specifications and standards reflecting best practice according to the above, have been developed primarily for specific fuel types, it is important to consider aspects related to combining different fuels on a multifuel energy station e.g. incompatibilities and coordinating measures according to chapter 7.2.5.1. Therefore, risk assessment related to the interaction with other fuels on-site should be performed e.g. by considering such risks in the risk assessments prescribed by the specifications/standards or by a separate risk assessment addressing such interaction aspects.

There may be different requirements and ways for permit and approval, depending on fuel amounts, where the maximum storage capacity for all fuels on-site needs to be considered.

To further support the development of an infrastructure with multifuel energy stations, an international ISO standard for Multi Energy Stations for vehicles (MES) is recommended to be developed and adopted as European standard. Such a standard should cover not only CBG/CNG, LBG/LNG, CH₂ and fast charging, but also LH₂ considering the interest of using such fuel for e.g. heavy trucks. Such a standard is recommended to be designed for stations with any combination of fuels (incl. stations with a single type of fuel and stations with conventional fuels as far as possible), thus replacing the current fuel specific standards for stations. Such a standard will provide a common structure of requirements and methodology to be applied regardless of fuel type, facilitating the design and verification of MES.

Requirements and methodology which are common for different fuels - and coordination aspects related to providing fuels with different safety-related properties - can be addressed in an effective and transparent way in such a standard for MES. Current national differences are recommended to be minimized as far as possible by such a standard, by normative requirements for installations (e.g. quantified safety distances) and classification of hazardous areas (e.g. quantified extent of zones).

7.2.6 Legislation according to EU provisions and standards related to safety

7.2.6.1 General

Sweden, Denmark, Finland and Germany are EU member states. Norway is an associated EFTA-member, based on the EEA agreement between EU and EFTA. EU directives are put into force by all member states of EU and EEA including these countries, by the countries themselves, by implementing the directives in their national legislation. Following this, common European provisions have been implemented in the national legislation of these countries (with some exceptions for Norway according to the EEA agreement). This means that these countries have to comply with European directives and regulations applicable for multifuel energy stations.

EU directives applicable for safety related aspects of fuelling stations can roughly be divided into the following two categories:

- 1) Product directives, to be considered for the design, production and trade of products, by manufacturers, importers and distributors
- 2) User directives, with safety requirements for workers, to be considered for the installation and operation by employers and users

In addition to such directives, there are also other directives which are more or less related to safety, including:

- Directive 2008/68/EC for inland transport of dangerous goods
- Directive 2014/94/EU related to the deployment of alternative fuels infrastructure (AFI)
- Directive 89/106/EEC (CPD) and regulation no. 305/2011 (CPR) related to construction products

7.2.6.2 Product directives related to safety

Specific product directives related to safety for products, are applicable for certain products or for products for certain use or associated with certain hazards. Such directives describe both essential health and safety requirements to be fulfilled for the products, and conformity procedures which must be followed. These requirements shall be fulfilled by manufacturers who intend to put products on the EU and EEA market.

With a few exceptions, these directives require CE-marking. The main aim is to allow the free movement of such products within the EU and EEA, and the member states are therefore not allowed to impose additional requirements or other barriers which prevent the free movement. The conformity procedures according to these directives may, or may not, require involvement of 3rd parties (e.g. notified bodies) to verify compliance with certain requirements. Compliance with product directives is normally indicated by a CE-marking affixed by the manufacturer and an EU Declaration of Conformity signed by the manufacturer.

Table 13 lists specific product directives related to safety, which may apply for multifuel energy stations or parts thereof.

There are also general product directives for producers and consumers, according to Table 14. They are no CE-marking directives.

Table 13 - Specific product directives related to safety for products to be considered for fuelling station equipment

EU Directive	Title
2014/34/EU (ATEX) ¹⁾	Equipment and protective systems intended for use in potentially explosive atmospheres
2006/42/EC (MD) ¹⁾	Machinery
89/686/EEC (PPE) ^{1) 2)}	Personal Protective Equipment
2014/35/EU (LVD) ¹⁾	Low Voltage Directive
2014/68/EU (PED) ¹⁾	Pressure Equipment
2010/35/EU (TPED)	Transportable Pressure Equipment (Pi-marking, no CE-marking)
2014/29/EU (SPVD)	Simple Pressure Vessels (pressurized with air or nitrogen)
Regulation (EC) No 1272/2008 ³⁾	Classification, labelling and packaging of substances and mixtures
<p>¹⁾ CE-marking directive.</p> <p>²⁾ As of 21 April 2018, Directive 89/686/EEC will be repealed by the new Regulation (EU) No 2016/425 for personal protective equipment.</p> <p>³⁾ This is a regulation, not a directive, which means that the requirements according to the regulation apply directly for the member states without any national measures to implement the regulation in the national legislation.</p>	

Table 14 - General product directives related to safety for consumers

EU Directive	Title
2001/95/EC (GPSD) ¹⁾	General product safety
85/374/EEC (extended by 1999/34/EC)	Liability for defective products
<p>¹⁾ The directive includes general safety requirements for products placed on the EU and EEA market, which aims at ensuring that only safe consumer products are sold in the EU. It applies in the absence of other EU legislation, national standards, commission recommendations or codes of practice relating to safety of products.</p> <p>Apart from these general provisions, certain categories of products are covered by sector specific legislation and product specific provisions. For products covered by sector specific legislation, the directive may apply to certain matters not covered by sector legislation. Work is ongoing to replace the directive with a regulation on consumer product safety and market surveillance.</p>	

7.2.6.3 User directives related to safety

User directives according to Table 15 are generally directed to employers (operating work places and/or using equipment). They shall take technical and/or organizational measures appropriate to the nature of the operation, in order to ensure the health and safety of workers.

Table 15 - Specific user directives related to safety for workers to be considered for fuelling stations

EU Directive	Title
1999/92/EC (ATEX User Directive)	Minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres
2009/104/EC	Minimum safety and health requirements for the use of work equipment by workers at work
2010/75/EU (IED) ¹⁾	Industrial emissions
96/82/EC and 2003/105/EC	Control of major-accident hazards involving dangerous substances
98/24/EC	Protection of the health and safety of workers from the risks related to chemical agents at work
¹⁾ To be considered for activities according to Annex I in the directive and, where applicable, activities reaching the capacity thresholds set out in that Annex.	

7.2.6.4 Standards supporting EU directives and legislation

Legislation in the countries based on EU directives for products, is complemented by national standards based on European standards, which provide more detailed information on requirements to be fulfilled to comply with the legislation. The actual countries (SE, NO, DK, FI and DE) are all members of the European standardization organizations CEN and CENELEC and thus obliged to adopt the standards produced by CEN and CENELEC (EN standards). Therefore, these standards represent best practice for these countries.

However, in some areas (e.g. user standards for installation and use), the standards may reflect minimum requirements, which do not prevent countries to apply requirements which are additional to those in the standard. Table 5 exemplifies such standards.

Product standards which are harmonized for CE-marking product directives (e.g. ATEX Directive 2014/34/EU), represents state of art and they are typically referred to as “harmonized standards”. Such harmonized standards are normally used by manufacturers of equipment, to comply with the essential health and safety requirements stated in the related directives. The member states are not allowed to require additional requirements beyond such essential health and safety requirements (reflected by the harmonized standards), to avoid technical barriers that hamper trade. Lists of such harmonized product standards can be found on the EU commission homepage for the relevant directive.

In addition to European standards, other nationally published information may be available in the countries, such as:

- national standards, which are not based on European standards
- guidelines from authorities and trade organizations

8 Annexes

8.1 References

- [1] ISO/IEC 80079-20-1:2017 Explosive atmospheres - Part 20-1: Material characteristics for gas and vapour classification – Test methods and data, Sub-clause 3.3.
- [2] IEC 60079-10-1:2015 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres, Sub-clause 3.6.12 and 3.6.13.
- [3] IEC 60079-10-1:2015 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres, Sub-clause 3.6.7.
- [4] ISO/IEC 80079-20-1:2017 Explosive atmospheres - Part 20-1: Material characteristics for gas and vapour classification – Test methods and data, Sub-clause 5.1.5.
- [5] IEC 60079-14:2013 Explosive atmospheres - Part 14: Electrical installations design, selection and erection, Table 4.
- [6] HyApproval, Handbook for Hydrogen Refuelling Station Approval, version 2.1, 2008.
- [7] EIGA DOC 06/02/E, "Safety in storage, handling and distribution of liquid hydrogen".
- [8] IEC 60079-10-1:2015 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres, Annex H.
- [9] SP Report 2012:55, Peter Bremer, Thomas Berg, "Certification and approval procedures in Scandinavia for hydrogen fuelling stations and fuel cell electric cars, H2moves Scandinavia (ISBN 978-91-87017-74-2)," 2012.
- [10] IEC 60079-10-1:2015 Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres, Sub-clause 3.6.7.

8.2 References and complementary information for Table 4

Table 16 - Safety related data for the properties of some fuels (incl. references)

Substance	Density relative to air	Diffusion coefficient in air (cm ² /s)	Flammability range (volume %)	Auto-ignition temperature (°C)	Temperature class	Minimum ignition energy in air (mJ)	Equipment group
Biogas ⁴⁾	0,9 ³⁾		6-26 ³⁾		T1 ³⁾		IIA ³⁾
Ethanol	1,59 ¹⁾	0,11 ⁸⁾	3,1–19,0 ¹⁾	400 ¹⁾	T2 ¹⁾		IIB ¹⁾
Hydrogen	0,07 ¹⁾	0,61 ⁹⁾	4,0–77,0 ¹⁾	560 ¹⁾	T1 ¹⁾	0,016 ¹¹⁾	IIC ¹⁾
LPG ⁷⁾	1,57 ³⁾	0,10 ¹⁰⁾	2-10 ³⁾		T2 ³⁾		IIA ³⁾
Methane ²⁾	0,55 ¹⁾	0,16 ⁹⁾	4,4–17,0 ¹⁾	595/600 ¹⁾	T1 ¹⁾	0,28 ¹¹⁾	IIA ¹⁾
Natural gas ⁶⁾	0,84 ³⁾	0,16 ¹³⁾	4-15 ³⁾		T1 ³⁾		IIA ³⁾
Petrol	3,0 ¹⁾	0,05 ¹⁰⁾	1,4 – 7,6 ¹⁾	280 ¹⁾	T3 ¹⁾	0,24 ¹²⁾	IIA ³⁾
Propane	1,56 ¹⁾	0,12 ¹³⁾	1,7–10,9 ¹⁾	445 ¹⁾	T2 ¹⁾	0,25 ¹¹⁾	IIA ¹⁾
Vehicle gas ⁵⁾	0,6 ³⁾	0,16 ¹⁴⁾	4-17 ³⁾		T1 ³⁾		IIA ³⁾

¹⁾ According to standard ISO/IEC 80079-20-1:2017, valid for certain ambient conditions. The data are the result of experimental determinations, and as such are influenced by variation in experimental apparatus and procedures, and in the accuracy of instrumentation.

²⁾ Industrial methane, such as natural gas, is classified as Group IIA, provided it does not contain more than 25 % (V/V) of hydrogen, according to standard ISO/IEC 60079-20-1:2017.

³⁾ According to Swedish handbook SEK Handbook 426 ed 5.

⁴⁾ Biogas incl. ~65 % methane

⁵⁾ "Fordonsgas" in Swedish (incl. ~97 % methane according to Swedish handbook SEK Handbok 426 ed 5). In Germany two qualities of CNG are offered for vehicles: H-Gas (High caloric gas) and L-Gas (Low caloric gas). The methane content for L-Gas is 80-87 % and the methane content for H-Gas is 84-99 %. The quality is defined by the German standard DIN EN 16723-2:2017-10.

⁶⁾ Swedish natural gas (incl. ~87 % methane)

⁷⁾ "Gasol" in Swedish (incl. 95 % propane)

⁸⁾ According to GSI Chemical Properties Database <http://www.gsi-net.com/en/publications/gsi-chemical-database.html>

⁹⁾ According to ISO/TR 15916:2015 (ed. 2), Table A.2

¹⁰⁾ According to report "Säkerhetsaspekter med vätgas som fordonsbränsle", 2005, D Gårsjö and M Niklasson, LTH and KTH, Table 3.4

¹¹⁾ According to IEC TS 60079-32-1:2013, Table C.2

¹²⁾ According to ISO/TR 15916:2015 (ed. 2), Table B.3

¹³⁾ According to EIGA DOC 06/02/E, Table "Properties of..."

¹⁴⁾ Approximated to the same diffusion coefficient as for methane, based on its content of methane.