*EUROPEAN COMMISSION*

*DG MOVE*

SEVENTH FRAMEWORK PROGRAMME

GC.SST.2012.2-3 GA No. 321592

# Evaluation of the recommended future standards

LNG Blue Corridors Project is supported by the European Commission under the Seventh Framework Programme (FP7). The sole responsibility for the content of this document lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the FP7 nor the European Commission is responsible for any use that may be made of the information contained therein.

| | | |
|---|---|---|
| Deliverable No. | LNG BC D4.5 | |
| Deliverable Title | Evaluation of the recommended future standards | |
| Dissemination level | Public | |
| Written By | Marta Tobar (IDIADA) | |
| Checked by | Marta Tobar - WP leader (IDIADA) | |
| Approved by | Judith Dominguez - techn. Coord. (IDIADA) | |
| Issue date | | |

# REVISION HISTORY

| Rev | Date | Author | Organization | Description |
|---|---|---|---|---|
| 0.1 | 13/02/2015 | Marta TOBAR | IDIADA | Initial Draft |
| 0.2 | 05/04/2017 | Javier LEBRATO | IDIADA | Additional content |
| 0.3 | 09/05/2017 | Flavio MARIANI | NGVA | Additional content and revision of the documents |
| 0.4 | 11/05/2017 | Marta TOBAR | IDIADA | Inclusion of the feedback received from the partners |
| 0.5 | 17/05/2017 | José BURGOS | IDIADA | Revision of the content |
| 0.6 | 21/06/2017 | Adriana LLADÓ | IDIADA | Inclusion of General Assembly and Review Meeting feedback |
| 0.7 | 29/06/2017 | Marta TOBAR | IDIADA | Revision of the content |
| 0.8 | 17/07/2017 | Per HANARP, Nadège LECLERCQ | VOLVO WESTPORT | Edits to the report |
| 0.9 | 19/07/2017 | Adriana Lladó | IDIADA | Revision of the content |
| 1.0 | 20/07/2017 | José Burgos, Adriana Lladó, Marta Tobar | IDIADA | Revision of the content |
| 1.1 | 21/07/2017 | Javier Lebrato | IDIADA | Revision of the content |
| 1.2 | 21/07/2017 | Adriana Lladó | IDIADA | Final review |

# Executive Summary

The LNG Blue Corridor project is focused on demonstrating the use of LNG as truck fuel and defining a road map for future large-scale development of the market. This report is the fifth deliverable of Work Package 4.

Work Package 4 – Harmonization and Standardization is focused on the further improvement and development of common standards and regulations related to LNG HD vehicles and fuel stations.

This report – 4.5 Evaluation of the recommended future standards – is written with the objective of continuing the work already developed in the previous deliverable. According to the recommended type-approval proposal (including the homologation process for both LNG stations and vehicles) this document analyses the current state of the art and provides new updates and recommendations that help with the deployment of LNG technology.

UN Regulation No. 110 (LNG vehicles) and the ISO 16924 (LNG stations) have been taken into account as reference documents. Other standards analysed are still under development in different international working groups and they will require further analysis in the future.

# Contents

# 1 Introduction

## 1.1 LNG Blue Corridors project

The LNG Blue Corridors project's aim is to establish LNG as a real alternative for medium- and long-distance transport - first as a complementary fuel and later as an adequate substitute for diesel. Up to now the common use of gas as fuel has been for heavy vehicles running on natural gas (NG) only for municipal use, such as urban buses and garbage collection trucks. In both types of application, engine performance and autonomy are good with present technologies, as they are well adapted to this alternative cleaner fuel.

However, analysing the consumption data, the equivalence in autonomy of 1 litre of diesel oil is 5 litres of CNG (Compressed Natural Gas) compressed to 200 bar. Five times more volume of fuel prevents the use of CNG in heavy road transport, because its volume and weight would be too great for a long-distance truck. This opens the way for LNG (Liquefied Natural Gas), which is the way natural gas is transported by ship to any point of the globe. NG liquefies at 162 °C below zero, and the cost in energy is only 5% of the original gas. This state of NG gives LNG the advantage of very high energy content. Only 1.8 litres of LNG are needed to meet the equivalent autonomy of using 1 litre of diesel oil. A 40-ton road tractor in Europe needs a tank of 400 to 500 litres for a 1,000 km trip; its equivalent volume with liquid gas would be 700 to 900 litres of LNG, a tank dimension that could easily be fitted to the side of the truck chassis. LNG therefore opens the way to the use of NG for medium and long-distance road transport.

LNG has huge potential for contributing to achieving Europe's policy objectives, such as the Commission's targets for greenhouse gas reduction, air quality targets, while at the same time reducing dependency on crude oil and guaranteeing supply security. Natural gas heavy-duty vehicles already comply with Euro V emission standards and have enormous potential to reach future Euro VI emission standards, some without complex exhaust gas after-treatment technologies, which have increased procurement and maintenance costs.

*Figure 1. Impression of the LNG Blue Corridors*

To meet the objectives, a series of LNG refuelling points have been defined along the four corridors covering the Atlantic area (green line), the Mediterranean region (red line) and connecting Europe's South with the North (blue line) and its West and East (yellow line) accordingly. In order to implement a sustainable transport network for Europe, the project has set the goal to build approximately 14 new LNG stations, both permanent and mobile, on critical locations along the Blue Corridors whilst building up a fleet of approximately 100 Heavy-Duty Vehicles powered by LNG.

This European project is financed by the Seventh Framework Programme (FP7), with the amount of 7.96 M€ (total investments amounting to 14.33 M€), involving 27 partners from 11 countries.

This document corresponds to the 5th deliverable within Work Package 4. This document analyses the recommended type-approval definitions for the homologation process of LNG vehicles and LNG stations respectively proposed in the previous deliverable, and updates them according to the current trends. This document will be available at the project website: http://www.lngbluecorridors.eu/.

## 1.2 Aim of this deliverable

At the beginning of this project, the lack of regulatory framework and common standards within the European Union was the main obstacle for a wide deployment of heavy-duty vehicles powered by liquefied natural gas (LNG) as well as the related infrastructure of LNG fuelling stations.

Nowadays, four years later, LNG trucks and LNG fuelling stations are a reality and can be seen in European roads. Regulations and standards have been published in order to allow this technology to be feasible and have proved to be another option for the road transportation industry.

Historically all on-board CNG related aspects were approved according to UN Regulation 110, but LNG was missing in its scope. Today UN Regulation 110 has been amended to include the type approval of LNG components and LNG vehicles. With this regulation in force, problems from the past such as the lack of harmonised regulatory framework for LNG vehicles have been overcome. LNG vehicles can travel across Europe without any inconvenience as it has been proved in the project.

The work developed by Technical Committee *ISO/TC 22/SC 41 Vehicles using gaseous fuels (previously known as Technical Committee ISO/TC 22/SC 25 Vehicles using gaseous fuels)* has been the base for the changes in UN Regulation 110. Also, ISO Standards regarding components and LNG vehicles have been working to harmonize and standardize all the aspects related to LNG uses: *ISO 12614 - Liquefied natural gas (LNG) fuel system components*. Technical Committee *ISO/PC 252 - Natural gas fuelling stations for vehicles* has been working on ISO Standards regarding LNG stations: *ISO 16924 - LNG stations for fuelling vehicles*.

Therefore, the aim of this deliverable is to provide a final analysis of the current state of the art and evaluate it according to the recommendations proposed in Deliverable 4.4. These recommendations take into account the homologation process of LNG heavy-duty vehicles and LNG stations. It also considers aspects such as safety, security and environmental limitations and missing aspects of current and forthcoming European regulations and standards.

For this purpose, ECE R110 (LNG vehicles) and ISO 16924 (LNG stations) have been considered as reference documents (among others), and those identified missing points and proposed modifications have been included when necessary.

# 2 Evaluation of the recommended future standards for LNG Vehicles

UNECE Regulation No. 110 amendment series 01 was considered in previous deliverables as a referent document. In the field of liquefied natural gas (CNG and/or LNG) this regulation applies to:

I. Specific components of motor vehicles using compressed natural gas (CNG) and/or liquefied natural gas (LNG) in their propulsion system
II. Vehicles with regard to the installation of specific components of an approved type for the use of compressed natural gas (CNG) and/or liquefied natural gas (LNG) in their propulsion system

The current version of the UN Regulation 110 is the amendment series 02, which entered into force on 8 October 2016.

It introduces changes in the labelling of some components, CNG and LNG (Valves), the markings in the surrounding area of the filling receptacle, the direction of gas discharged from the pressure relief device, changes regarding the type of construction of some CNG tanks and the procedure to approve them. LNG vehicles continue to be a possible solution totally approvable.

## 2.1 Venting system

The design and operation of the station and vehicle shall minimize the venting of boil-off gas to the atmosphere. In this respect, NGVA Europe has elaborated a "zero venting target" policy.

According to ECE R110 vehicle LNG tanks shall have a design hold time (build without relieving) minimum of 5 days after being filled net full and at the highest point in the design filling temperature/pressure range. According to SAE J2343 this requirement is the same.

### 2.1.1 Proposal in Deliverable 4.4

Alternatives in order to recover the gas from the vehicle tank as a result of boil-off phenomena before being released into the atmosphere should exist.

Stations should be also designed to be able to accept gas from the vehicle tanks when the tank arrives with excess pressure prior to the refuelling process. This vented gas should be able to be transferred either through the main fuelling coupling or through an additional dedicated venting coupling. In the case of a dedicated venting coupling, then this coupling interface should be standardized.

### 2.1.2 Evaluation

In April 2017, the natural gas industry members of NGVA Europe have formally adopted the above mentioned "Zero-Venting Target" policy for routine operations in all newly built CNG and LNG retail stations. In order to meet this commitment, CNG and LNG retail stations will be designed in such way that methane emissions ('fugitive emissions') are minimized at all times during operation.

All the LNG vehicles currently commercially available in Europe (as of July 2017) require boil-off gas from the vehicle tank to be vented back to the station through a dedicated vent connection using Macro Technologies type connector. Almost all LNG stations (except maybe for a few old ones) in Europe are able to recover vent gas from the vehicle tank through this dedicated line.

ISO group ISO/TC 22/SC 41/WG 4 is working in the ISO NP 21104 *"Road Vehicles - Liquefied natural gas (LNG) low pressure refuelling connector"*. This standard will establish the requirements to be fulfilled by a new LNG nozzle with a nominal working pressure of 1,8 MPa (18 bar) for refuelling and venting via one single line. This single line solution reduces the operation complexity, risk of human error and therefore increases safety of LNG station operation.

New solutions will come with this new standard that is not compatible with the existing ones. Some partners reported that stations should admit different solutions since it would be impossible to recall all the vehicles in the market. At this stage there has been no transition plan defined to allow the market to smoothly move to this new standard.

According to discussions between some partners from the consortium and major LNG station equipment manufacturers in Europe, the current status (as of July 2017) of LNG stations' compatibility with this requirement can be summarized as follows.

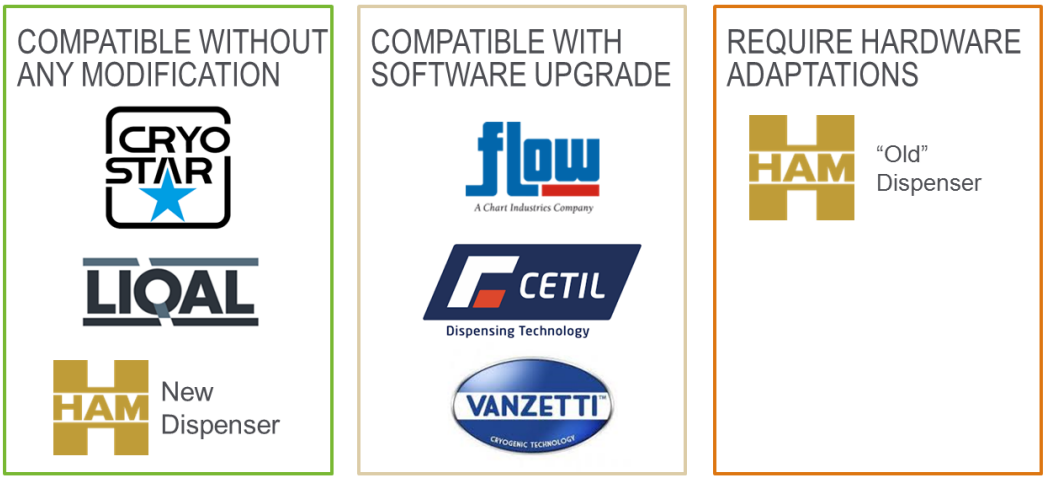


*Figure 2. LNG Dispenser Compatibility (source: Volvo, June 2017)*

LNG Dispenser Compatibility Overview:

- LNG stations equipped with Cryostar, Liqal or the new HAM dispenser are able to accept vent gas through the fill line without any modification;
- LNG stations equipped with Flow, Cetil or Vanzetti dispensers won't require any hardware modifications but their software will have to be upgraded with a new automated fuelling and venting procedure;
- LNG stations equipped with the "old" HAM dispenser will require both hardware and software modifications to be able to accept vent gas through the fill line, with several solutions to be considered on a case by case basis.

Compatibility of other stations, particularly those with proprietary dispenser design, is still being analysed. As it is crucial for all LNG trucks to be able to vent back to station, this topic should continue to be monitored in order to ensure adequate compatibility of LNG stations.

Another feedback received from the partners is that ISO 12617 *"Road vehicles -- Liquefied natural gas (LNG) refuelling connector - 3,1 MPa connector"* is in process of being included in R110, and it should be decided whether or not ISO 21104 should be included there too.

## 2.2 Couplings and receptacles

ISO 12617:2015 *"Road vehicles - Liquefied natural gas (LNG) refuelling connector - 3,1 MPa connector"* talks about the connector design and is the most used one by the manufacturers. This ISO does not cover the compatibility between nozzles and receptacles (the ISO standard only refers to receptacle geometry; not nozzle). The ISO 12617 includes an agreement about compatibility; new homologations must include receptacles compatible with all nozzle fixation systems.

### 2.2.1 Proposal in Deliverable 4.4

Only harmonised configurations nozzles-receptacles should be allowed in Europe. A hybrid solution between J. Carter/Macrotech and Parker Kodiak would be a solution, but there is not any homologated solution in the market. Therefore, this solution is hardly achievable at present. Nevertheless, nowadays most European stations are using JC Carter as a good solution which can be considered as a compatible solution (see Figure 3).

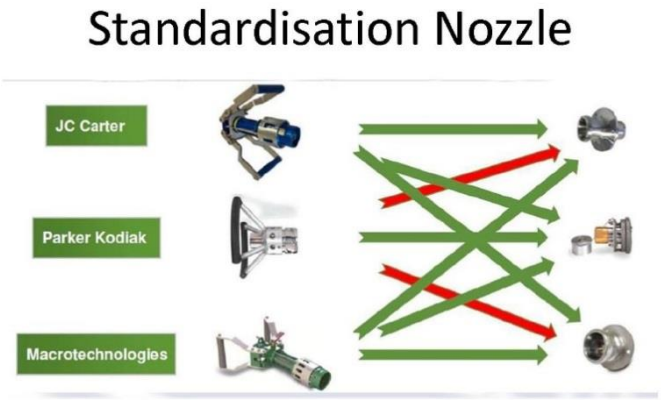


*Figure 3. Interchangeability between LNG nozzles and connectors at present on the market*

ISO 12617 (published last 18th March 2015), defines the LNG refuelling connector – 3.1 MPa connector. It is proposed to take into consideration this standard. This ISO is applicable only to such devices designed for a maximum working pressure of 3.4 MPa (34 bar). LNG fuelling connector consists of, as applicable, the receptacle and its protective cap (mounted on the vehicle) and the nozzle.

### 2.2.2 Evaluation

Until now, it has not been compulsory to standardize the nozzle and receptacle compatibility. The fact is that there are refuelling stations equipped with nozzles not compatible with all the vehicles running on LNG.

Currently ISO 12617 standardizes the nozzle and the recent ISO 16924 standardizes the station equipment. However, there is an ongoing process to define a new nozzle with the venting incorporated (ISO NP 21104).

Both, the truck and LNG tank manufacturers and the truck and station operators, shall define the correct standard or be ready to equip all stations for all available refuelling solutions.

## 2.3 Installation of the tank

Fleet operators request LNG-powered trucks that are compatible with low-trucks, and therefore use a 95 cm 5th wheel height - a lower mounting height requirement. In case of low-trucks, the truck's chassis sits lower to the ground, which in turn means that the diameter of LNG tanks needs to be smaller.

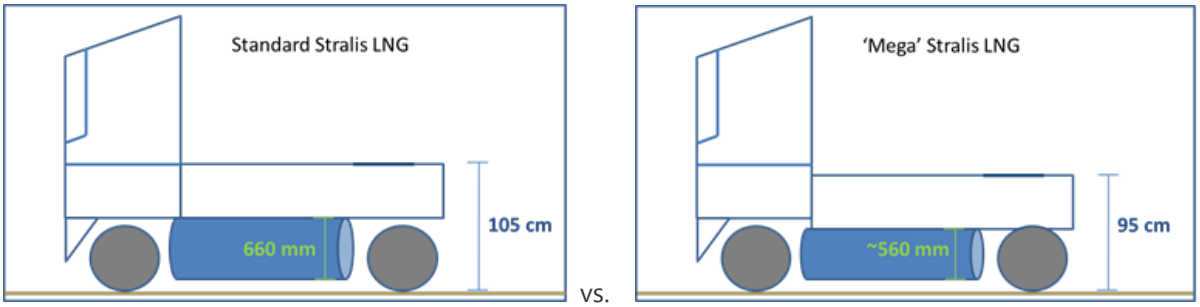


*Figure 4. Standard stralis LNG vs. Mega stralis LNG*

### 2.3.1 Proposal in Deliverable 4.4

Currently all the possibilities are covered by Regulation No 110. LNG tank height should be enough to ensure safety.

### 2.3.2 Evaluation

As explained in Deliverable 4.4, low height vehicles are still a problem for vehicle manufacturers due to the reduced dimensions of the LNG tank. The manufacturing of new tanks is being a reality thanks to the presence of more than two manufacturers who have approved LNG tanks. At this time, the manufacturers will have to evaluate the market needs in order to offer the best solution.

## 2.4 Type-approval of dual-fuel retrofit systems at Euro VI

Supplement 1 to the 06 series of amendments of Regulation No. 49 defines the approval process for dual-fuel engines.

The Heavy-Duty Dual-Fuel Task Force, which was part of the Informal Group on Gaseous Fuelled Vehicles from GRPE (GFV, which was discontinued in June 2016), created a document regarding a new regulation on uniform provisions concerning the approval of specific LPG (liquefied petroleum gases) or NG (compressed natural gas/bio-methane/liquefied natural gas) dual-fuel retrofit systems and dual-fuel retrofitted engines to be installed in heavy-duty applications.

During its 73rd meeting in Geneva, on 9 June 2016, GRPE approved a new UNECE Regulation for the certification of dual-fuel conversion systems (retrofit) for Diesel HD engines (document: ECE/TRANS/WP.29/GRPE/2016/12). To address some issues risen by the retrofit operators about the new Regulation, a new formal document has been published and discussed in November 2016. This document entitled " Proposal for a new regulation on uniform provisions concerning the approval of Heavy Duty Dual-Fuel Engine Retrofit Systems (HDDF-ERS) to be installed on heavy duty diesel engines and vehicles" ECE/TRANS/WP.29/2016/110 was discussed in the 170th session of the ECE TRANS WP 29 (Geneva 15-18 November 2016) item 4.12.1 of the provisional agenda. This document applies only to EURO V vehicles. The acceptance of this proposal made the adoption of the new Regulation on retrofit dual fuel less problematic for the operators of this sector, while ensuring the due quality of dual-fuel conversion in terms of emissions.

This new UN Regulation No 143 entered into force last 19th June 2017.

### 2.4.1 Proposal in Deliverable 4.4

In Deliverable 4.4, the market was waiting for the approval of a new Regulation on uniform provisions concerning the approval of NG dual-fuel retrofit systems and dual-fuel retrofitted engines to be installed in heavy-duty applications. Postures from different European countries are not the same; further development is required in this aspect.

### 2.4.2 Evaluation

The retrofit market is clearly one of the most important issues ongoing regarding development of the transition from diesel to gas as a fuel for trucks. The lack of extended refuelling infrastructure in Europe is a burden which so far discouraged some vehicle manufacturers from strongly investing in natural gas truck solutions for the time being. Therefore, vehicles retrofitted from diesel to Dual-Fuel play a very important role as a bridge on this matter. If designed for this option, Dual-fuel vehicles can still run on diesel alone in places where the CNG/LNG refuelling infrastructure is missing while can provide high powerful solutions (up to 560 hp) with more than 50% diesel replacement per gas. Now, also some high power natural gas fuelled engines, e.g. 400 hp (with a spark ignition solution) are available from OEMs like IVECO. More OEMs will follow on this same line, by increasing the maximum power output and running range of the dedicated (spark ignition) LNG HD vehicles that they have put on the market in the recent past.

UN Regulations have been enforced both for OEM and retrofit dual-fuel.

UN Regulation R.49 was amended back in 2014, to include requirements for HD Dual Fuel Vehicles made by OEM. A new Regulation for HD DF Retrofit systems was then presented and approved at GRPE meeting on 09/06/2016 in Geneva. The Dual-Fuel Retrofit regulation moved subsequently to approval by WP29 in November 2016. After the usual 6-8 month period, whereby Contracting Parties can agree/make comments on the regulation, it is anticipated to come into force by the third or fourth quarter of 2017.

The Heavy Duty Dual-Fuel retrofit new regulation includes the requirements for the type approval of retrofit systems intended for installation on a Heavy Duty diesel vehicle to enable its operation either in diesel mode or in dual-fuel mode. Only Euro IV, Euro V and EEV vehicles are included. In some countries like United Kingdom, Italy, Spain, and The Netherlands, the use of retrofitted solutions became popular in the past, and could potentially grow at the condition that new technological solutions to retrofit Euro VI vehicles to dual fuel become commercially available.

Among the aims of the new Regulations there are the following:

Keep the desired environmental level after the retrofit, not compromising polluting or greenhouse gas emissions; have a good feasible retrofit system in order to permit the diffusion of the retrofit technology; for dual fuel mode requirements, the manufacturer of the retrofit system could choose between two options:

- (1), all emission limits for dual-fuel mode as specified in the applicable R49 series of amendments apply.
- (2), NOX, PM and CO emission limits for dual-fuel mode as specified in the applicable R49 series of amendments apply; NMHC emissions shall not exceed the R49 limit (or those of the engine before retrofit); the retrofit CO2 ratio (back-to-back test):
    - CO2 + CH4 (as CO2 equivalent) ≤ CO2 of the original Diesel engine

## 2.5 Vehicle interlock system

It is possible that the filling nozzle is included in the vehicle interlock system to not allow the engine to start, but the vent coupling on the tank is outside the interlock flap thus allowing the engine to start and the truck to be driven away. It could cause an incident if only the refuelling line is pulled off.

Nevertheless, to include a stop in the vehicle interlock system when the filling hose is connected does of course minimize the drive away accidents. But if there is a potential emergency situation, it can be of great importance that the vehicle has the possibility to quickly leave the station.

Regardless, the filling hose of the station should be equipped with a breakaway coupling to ensure that in the case of a drive away incident, the damage is limited and the leakage is controlled.

### 2.5.1 Proposal in Deliverable 4.4

Make mandatory the existence of an alarm signal to avoid to switch on the engine when the filling hose or the vent couple is still connected, in the case that it is still possible to drive the vehicle.

Make breakaway coupling on the filling hose of the station mandatory.

### 2.5.2 Evaluation

At this moment UN Regulation 110 has no requirements on that. It is not compulsory to install any device to prevent the break of the filling hose during the refilling operation. However, it is mandatory for the station and in every filling hose that a device is installed to prevent leakage in case of a break in the filling hose during the refilling operation due to movements of the vehicle (i.e. excess flow valve).

As the vehicle cannot be equipped with a breakaway system installed in the piping, the *ISO 16924:2016 Natural gas fuelling stations — LNG stations for fuelling vehicles,* proposes solutions concerning this issue:

Section 3 "Terms and definitions" the breakaway device is the coupling which separates at a predetermined section when required and each separated section contains a self-closing shut-off valve which seals automatically. The hose assembly is the hose, or hoses, with ancillary components, such as bend restrictors, breakaways and nozzles, attached.

Section 7 "Fuel supply to the fuelling station". In cases where offloading from an LNG tanker not equipped with anti-drive-away equipment is permitted, a breakaway coupling element with check valves on both ends must be installed at the refuelling station side of the LNG offloading hose.

Section 10 "Dispensers". The typical LNG dispenser components are:

- nozzle(s) for fuelling LNG with or without vapour return/recovery;
- hose(s) for fuelling LNG with or without vapour return/recovery;
- hose(s) for vapour recovery when not integrated with the fuelling hose;
- dummy receptacle or parking dock for the nozzle when the fuelling hose is not in use;
- breakaway device(s) when not part of the hose assembly;
- flow meter(s);
- optional LNG vessel to contain the flow meter;
- temperature and pressure sensors and transmitters;
- electronic evaluation unit (optionally communicating with payment terminal when present);
- monitor displaying quantity, price etc.;
- pipe work and control valves, including thermal and pressure relief valves;
- electrical and pneumatic power supply;

The breakaway system must interrupt the hose to dispenser connection at a defined place in case of excessive force. It must close the separated parts to prevent spillage of LNG from any of both the parts. For this purpose check valves must be installed at each of the separated parts. Two check valves in series can be required by some local regulations. The disconnection force (the axial force in the fuelling hose) of the breakaway device must, in any direction, be:

- less than 850 N for high flow refuelling connectors according to ISO 12617; and
- less than 500 N for smaller refuelling connectors; and
- less than 70% of the allowed extension force of the fuelling hose; and
- less than 80% of the allowed force in the hose with respect to the maximum allowed load of the refuelling connector without leak or damage as defined in ISO 12617 or elsewhere for other refuelling connectors.

The fuelling hose assembly consists of: the fuelling nozzle; the hose; optionally, a breakaway system (if not already part of the dispenser); a connection to the dispenser.

## 2.6 Weights and dimensions for LNG vehicles

Current situation:

Directive (EU) 2015/719 of the European Parliament and of the council of 29th April 2015 amending Council Directive 96/53/EC laying down for certain road vehicles circulating within the Community the maximum authorised dimensions in national and international traffic and the maximum authorised weights in international traffic (published last 6th of May 2015), establishes that the extra weight that may generate the use of alternative powertrains, including LNG systems, in heavy duty vehicles or buses, but contribute to reduce pollution, should not be counted as part of the effective load of the vehicle, since this would penalise the road transport in economic terms. However, the extra weight should not result in the load capacity of the vehicle being increased either.

According to this Directive, the maximum authorised weights of alternatively fuelled vehicles shall be:

- Motor vehicles other than buses: maximum weight of 18 Tonnes is increased by 1 Tonne due to the additional weight required for the fuel technology.
- Two axle buses: 19.5 tonnes.
- Three-axle motor vehicles: 25 tonnes, maximum authorised weight is increased by 1 Tonne due to the additional weight required for the fuel technology
- Three axle articulated buses: 28 tonnes, maximum authorised weight is increased by 1 Tonne due to the additional weight required for the fuel technology.

These new measures are in line with the current UK's action plan described in Deliverable 4.4. This action plan states that a vehicle can exceed its gross allowable weight by 3% so long as it does not exceed the design weight of the axles and infringe on braking performance. For example a 40,000kg truck could in fact carry 41,200 kg so long as axle design weights are not exceeded.

### 2.6.1 Proposal in Deliverable 4.4

Check the Commission's work on the review of the EU type approval legislation. It is necessary to check if adopted measures regarding mass and dimensions of LNG vehicles are in line with current necessities.

Besides the maximum authorised weight, it is necessary to increase the weight per axle. The weight of the LNG tank is not necessarily distributed on all axles in the same way as the rest of the load and vehicle weight.

### 2.6.2 Evaluation

Commission's work has been checked and there have not been any updates regarding this regulation. Overall permitted weight is increased up to 1 Tonne but the axle weight has not changed. This proposal will not solve the vehicle weight problem due to the irregularity of the tanks that affects differently the axles' weight.

Directive (EU) 2015/719 does not include articulated vehicles other than buses (articulated trucks; vehicle+semi-trailer). Their maximum authorised weight of 40 tonnes should also be increased by 1 tonne for alternatively fuelled vehicles.

## 2.7 Strategies for reusing in the vehicle the recovered boil-off gas from the tank

If the vehicle has incorporated an on-board auxiliary tank able to recover/store the boil-off gas as an alternative to releasing the gas into the atmosphere, several strategies can be considered as mentioned in Deliverable 4.4.

There is still more work required by system suppliers to develop effective solutions for reusing boil-off gas. This research is currently at an early stage. Even though a number of strategies are technically feasible, they do increase system complexity and cost. It is therefore important to identify robust and cost effective solutions before implementing any of them at a large scale.

### 2.7.1 Proposal in Deliverable 4.4

During normal operation of an LNG vehicle, venting of gas shall be kept to a minimum. The need for venting is to a large degree related to the use of the vehicle. An information kit explaining best practice to avoid venting should be developed and the recommended practices should be evaluated.

### 2.7.2 Evaluation

According to SAE J2343 there should not be methane emissions during the normal operation of the vehicle. UN Regulation 110 makes mandatory that the gas supply system shall be leak-proof but allows releasing gas through the pressure release device and the venting system in case of overpressure in the LNG tank. However systems to recover or use the vented gas should be included in the vehicle and the regulations should be adapted to this necessity if needed.

The vehicle operation manual proposed in the following paragraphs shall also contain the best practices to avoid venting during the normal operation of the vehicle with special attention to the parking time.

Those natural gas vented recovering systems should be reliable, cost effective and should not increase the mass of the vehicle, which is a critical factor. If it is not possible to develop such kind of systems, then parking areas destined to long-term parking of LNG vehicles should be equipped with systems to recover the boil-off gas vented, and use it in the domestic grid or other uses.

Workshops also should be equipped with those kinds of devices. SAE J2343 makes mandatory that a vehicle under reparation or maintenance shall have the venting system connected to a safe outdoor location. In case of LNG tank maintenance, the LNG tank shall be defueled before any operation of removing or maintenance. The disposal of the recovered gas from the tank shall be according to local regulations, so a recovering system should be able to introduce the recovered gas into the domestic grid or other uses in workshops.

## 2.8 ADR issues

### 2.8.1 Prevention of fire risks

The Working Party on the Transport of Dangerous Goods (ECE/TRANS/WP.15) adopted on its ninety-ninth session held in Geneva from 9 to 13 November 2015 the proposals for amendment to annexes A of ADR by which the use of Liquefied Natural Gas (LNG), Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) will be included as fuel for vehicles carrying dangerous goods.

### 2.8.2 Proposal in Deliverable 4.4

Maintain the measures of the agreement M276 regarding the allowance of trucks powered by LNG technology to transport ADR goods until version 2017 of ADR will be in force.

The inclusion of CNG components and trucks into the ADR document amended is important since some OEM's LNG solutions still include CNG tanks.

### 2.8.3 Evaluation

This topic was covered by the group WP15 ADR. After quite extensive discussion in the team of experts, the ADR Regulation has been successfully amended, and the new text with amendments is in application since January 2017 to allow LNG and CNG propulsion for ADR-certified vehicles, except vehicles of type EXII and EXIII (i.e. for transport of explosives), for which only compression ignition engines are admitted, propelled only by fuels having a flash point at or higher than 55°C (i.e. diesel oil).

Among the amendments agreed there is a limit to the maximum content of fuel allowed in the vehicle tank (i.e. on the fuel for the vehicle engine). The limit is the amount of energy or mass corresponding to 1,500 litres of diesel oil. This limit will apply to all vehicles besides those certified to ADR Regulation.

Another important provision included is that all safety vents of fuel must be directed upward, as this is deemed as the safest vent direction.

## 2.9 Tunnel restrictions

The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) establishes some road tunnel restrictions for the passage of vehicles carrying dangerous goods, in Chapter 1.9.5 *Tunnel restrictions*, and Chapter 8.6 *Road tunnel restrictions for the passage of vehicles carrying dangerous goods*. Nevertheless, Chapter 1.1 *Exemption*, states the exemption related to the carriage of gases and liquid fuels when the fuel is contained in the tanks of a vehicle, performing a transport operation and destined for its propulsion or for the operation of any of its equipment. This means that a CNG or LNG fuel vehicle can be used to transport dangerous goods, with some limitation for explosives.

ADR prescribes anyway a limit on the LNG or CNG used as fuel for vehicles, at the energy or mass equivalent to 54.000 MJ, corresponding to a quantity of 1.500 litres diesel. This limit applies to all vehicles, not only to vehicles for transport of dangerous goods.

### 2.9.1 Proposal in Deliverable 4.4

The European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR) is exempt for vehicles that use the dangerous good as propulsion fuel. However, according to the International Maritime Dangerous Goods (IMDG) code, the maritime industry will accept LNG vehicles and LNG tankers on ventilated decks. The acceptance of this by the tunnel or bridge operators will facilitate the LNG technology deployment.

### 2.9.2 Evaluation

Concerning traffic through tunnels, of LNG and CNG vehicles in general, (whether or not ADR), national regulations must be taken into account. In the case of France, there is a minor restriction when driving across the Mont Blanc tunnel, where a special inspection must be done the first time a LNG not-registered truck tries to drive across it. After checking the trucks once, this vehicle will be equipped with a special informative badge which allows it to drive thought the tunnel in further occasions.

In the case of UK, as already explained, neither LNG nor CNG vehicles are allowed to drive through Eurotunnel. This can be hardly changed shortly. The same solution as in the case of Mont Blanc tunnel might be applicable with the support of the national entities: special badge can be provided to those LNG trucks which go and back regularly trough these tunnels.

## 2.10 Fuel quality

Gas quality does vary depending on the source of LNG, the production of LBG and the handling of the fuel along the distribution chain up to the delivery of the truck. Impurities in the gas, like sulphur, particulate matter and siloxanes can deteriorate the engine and after-treatment system, resulting in costly service and repair. Sulphur content below 10 ppm (as for diesel and gasoline) is required for high performance lean burn engines such as those using the HPDI technology. The variation of the gas quality when it comes to Wobbe Index (WI) and Methane Number (MN) does also affect the possibility of optimising truck engines, and will also continue to be an issue of interest after the launch of trucks on the market. Therefore, continuous focus on gas quality will remain a critical area to keep track of.

Despite gas quality may vary due to external factors, each country has its own way to manage gas quality. Japan and the USA are able to keep a similar gas quality over the country thanks to different management processes. From the other side, Europe shows a high diversity between the different countries. To get a similar quality on Europe, several measures have to be applied starting by introducing quality standards. To establish these standards different processes can be used such as:

- Ballasting ($N_2$ injection to reduce the Wobbe Index)
- Propane / Butane injection or removal (for small Wobbe Index corrections)
- $CO_2$ or $N_2$ removal (only applicable for pipeline gas)
- Blending (Blend of LNG coming from different sources)

These measures can help to make the LNG available throughout Europe more interchangeable.

### 2.10.1 Proposal in Deliverable 4.4

In order to ensure the European import/export market it is necessary to create, or develop gas quality standardization. Progress in gas interchangeability is vital for market development and work in the study of vehicle technology.

Fuel quality for gas for automotive use must ensure the possibility to develop high performance engines and vehicles that fulfil current emissions legislation (Euro VI step D) as well as foreseen future additional requirements for vehicles.

One important topic recommended about the LNG quality is to ensure a common MN calculation method for the standardization in the European market and to have reliable criteria. It is important to know the MN and WI index to optimise engines.

### 2.10.2 Evaluation

During the last part of 2016 new ISO and CEN regulations regarding natural gas quality had been published. However, more activity and discussions of their amendments are expected during early 2017.

#### 2.10.2.1 CEN/TC408

CEN/TC 408 held a meeting on September 2016. Last draft of EN 16723-2 "Natural gas and biomethane for use in transport and biomethane for injection in the natural gas network - Part 1: Specifications for biomethane for injection in the natural gas network" was approved. Proposals for the Part 2 of this regulation have been sent to CCMC, then ballot started in October 2016 and it has been approved and published in July 2017.

EN16723-2 gives a normal grade specification with sulphur level of 30 mg/Sm3. This specification is in most cases appropriate for conventional stoichiometric engines with three way catalyst, available in the market today. However for newer high performance engines like e.g. those using the HPDI technology, the normal grade specification is not sufficient. For such engines requiring low sulphur fuel (and tighter specifications on e.g. Wobbe Index, Methane Number etc.), EN 16723-2 specifies a "dedicated grade" indented for vehicles in dedicated fleets. The recommended dedicated grade is specified in Annex D.

Particulate content is one parameter that requires further investigations; in particular there is need for additional development of test methodology. A particle content of maximum 10 mg/l is required for automotive applications. One way to ensure this is to add a filter on the fuel station and therefore the recommendation in EN16723-2 is: "Fuelling stations providing LNG should ensure a maximum particle contamination of 10 mg/l of LNG to protect the automotive vehicle system from debris, providing performance equivalent to a filter with maximum pore size of 5 µm nominal and 10 µm absolute with 90 % efficiency."

#### 2.10.2.2 ISO/TC193

The ISO TC193/WG2 Quality Designation, which covers the standards on natural gas and on CNG quality, edited the previously published ISO 15403 parts 1 and 2 titled "Natural gas -- Natural gas for use as a compressed fuel for vehicles". They also edited the technical report ISO/TR 22302:2014 *"Natural gas- Calculation of the methane number (MN)"*.

Even though there are several methods for MN calculation, experts tend to agree that the most reliable one currently is the AVL method, which is proprietary, hence not available for public domain. Public MN calculation methods also exist, such as the MWM method described in Annex A of EN16726 and for which there is a public software available. However these different methods are not considered sufficient to properly characterize the knock resistance of NG fuels for transportation applications.

Therefore work is currently underway in the TKI project, with financial support from the Dutch government, to define a new index enabling more accurate knock prediction. This new method, called PKI (Propane Knock Index), uses methane/propane scale and accounts for the three changes in physical/chemical processes when changing fuel composition, i.e., autoignition chemistry, burn rate and thermophysical properties. The goal of the TKI project is to develop verified algorithms to characterize the knock resistance of LNG fuels for three engines, a spark-ignited CHP engine, a dual-fuel engine used in the maritime sector and a stoichiometric truck engine. The resulting algorithm is expected to serve as input in the international discussions regarding standardization, but could also be used by individual parties to assess the risk of engine knock for their own engine/fuel combinations. This activity is of interest to vehicle OEMs and will be ground for debate within the industry once the new PKI calculation tool will be published.

#### 2.10.2.3 CEN/TC234/WG11

CEN/TC234/WG11 has published in December 2015 the standard EN16726 Gas infrastructure - Quality of gas – Group H. It describes different characteristics regarding gas quality i.e. gas parameters and their limits. For filling stations connected to the gas network it is difficult to change the quality of the gas and most of the parameters in the automotive fuel specification are limited by values set in the network standard. For LNG filling stations the situation is less limited since they are typically not connected to the gas network.

#### 2.10.2.4 Sector Fora Gas

In 2015 CEN Sector Fora Gas formed a WG in order to evaluate EN16726. Their main purpose was to include more parameters such as Wobbe Index and lower sulphur level as required by many end user stakeholders, such as heating and electricity generation, stationary engines and automotive industries. EN 16726 describes gas quality characteristics but Wobbe Index (WI) is not included, for that reason it is considered that EU Mandate M/400 Gas quality is not fulfilled. Limited progress has been achieved so far.

# 3 Type Approval Text Proposal for LNG Stations

In late~~st~~ 2016 *ISO 16923:2016 Natural gas fuelling stations — CNG stations for fuelling vehicles* and *ISO 16924:2016 Natural gas fuelling stations — LNG stations for fuelling vehicles* were published.

CEN, the European Committee for Standardization, has just reconvened the CEN/TC 326 "*Gas supply for Natural Gas Vehicles*"~~,~~. In April 2015, two new working groups were officially formed with the mandate to edit the European standards for refuelling stations of CNG and LNG by 2016, which was a key request of Directive 94/2014/EU on deployment of alternative fuels infrastructure. Regarding LNG, new Standard must be compatible with ISO 16924.

The scope of the Directive on alternative fuels infrastructure in terms of harmonised European standards for liquefied natural gas supply includes:

- LNG refuelling points for waterborne vessels compatible with ISO/TC 67
- LNG connectors and receptacles compatible with UN Regulation 110 ISO 12617
- LNG and L-CNG refuelling points for motor vehicles compatible with ISO 16924

## 3.1 Fuel quality

See 2.10. Fuel quality

## 3.2 Refuelling pressure and temperature

LNG refuelling pressure is not harmonized in Europe, as limitations are not established in any regulation. Main delivery pressure in practice is 8 bar, but there are some exceptions. For instance, delivery pressure in Sweden is from 6 bar to 12.5 bar, in the Netherlands is 3.7 bar and 18 bar, and in Portugal and Spain 16 bar is also possible. In Europe in general, there can be two levels of delivery pressure (8 bar or 18 bar) corresponding to the equilibrium pressure at 2 different temperatures and to the needs of different Euro V vehicle models. However all current Euro VI LNG vehicles using spark ignited engine technology are now able to accept LNG at 8 bar, so there is only a minority of 18 bar LNG trucks still in operation. Manufacturers and designers agree to unify to only one technology.

Moreover the trend in the coming years will be to further reduce the LNG storage pressure/temperature ratio on the vehicle, which will increase the vehicle range thanks to higher fuel density. In addition, lower pressure/temperature will increase vehicle hold time i.e. increase number of days until potential venting to the atmosphere through the pressure relief valve. Pump assisted natural gas vehicle systems (also called "active" LNG systems: LNG pump integrated in the vehicle tank like the new Volvo FH LNG and Volvo FM LNG Euro VI trucks, vehicles using the HPDI technology) can use LNG storage systems at very low pressure/temperature ("cold" LNG e.g. at 1-3 bar). However, LNG systems that depend on the vehicle tank pressure to provide flow (also called "passive" LNG systems) have limitations on minimum pressure and are not likely to be able to operate below 8 bar.

Even though all current Euro VI systems use passive LNG systems, this is expected to change in the near future, also for spark ignited engines: engine technology experts agree that further optimisation and efficiency improvement of spark ignited natural gas engines will require engines to operate at higher pressure (e.g. ~50 bar), which means LNG vehicles using such engines will also require active LNG systems and will therefore prefer refuelling with "cold", i.e. unsaturated LNG. As this type of engine and vehicle is currently under development e.g. within the EU funded HDGAS project (Horizon 2020 program), it can reasonably be expected that LNG vehicles using active LNG systems (either with spark ignited or HPDI engines) will become the new standard in the 2020's.

### 3.2.1 Proposal in Deliverable 4.4

Short term: the goal should be to standardise on 8 bar station pressure as the lowest pressure system that will satisfy vehicle systems with and without LNG pumps.

Longer term: lower pressures should be the target in order to minimize potential venting and maximize vehicle range.

### 3.2.2 Evaluation

The above analysis of current and future Euro VI LNG vehicle requirements in terms of delivered LNG pressure and temperature shows that vehicles that can refuel with "cold", unsaturated LNG are expected to become more broadly available across Europe in the coming years because of their increase in operational range and hold time. The EU Commission and stakeholders should promote OEMs to develop solutions for these pump assisted natural gas vehicle systems.

It is highly recommended for LNG stations to prepare for these new requirements, in order to be able to supply cold LNG (e.g. Volvo trucks prefer a pressure of ~4 bar) when their customers start operating trucks with active LNG systems, in addition to LNG at 8 bar for trucks with passive LNG systems.

As a first preparation step, it is suggested for LNG stations to use external saturation systems (e.g. "saturation on the fly") that can be by-passed when fuelling trucks with active LNG systems instead of bulk saturation of the LNG in the station's storage tank which is currently the most common system.

As a next step, station operators will need to decide how the LNG pressure/temperature will be selected each time a truck comes to refuel. A number of options can be considered, ranging from manual selection e.g. on the display panel or button on the dispenser to fully automated selection e.g. based on license plate recognition. It would be recommended that all industry players agree on a common standard for the European market.

## 3.3 Consumer information about LNG price

Information provided by stations regarding LNG price and specific features should be normalized.

An important factor for the successful market introduction of alternative fuels is comprehensive and transparent consumer information. Understandable and comparable prices are an important building block. The fuels offered at our filling stations are priced in different sales units without this being visible on the filling station totem. The energy content per sales unit varies greatly among different fuel options in some cases. It is therefore not possible to directly compare different fuel prices on the filling station totems.

### 3.3.1 Proposal in Deliverable 4.4

According to "Initiative for Natural Gas-Based Mobility – Natural Gas and Biomethane as Fuels" and in order to facilitate price comparison for the customer, it would be beneficial to indicate the price of LNG in €/PLE (Petrol Litre Equivalent) in addition to the price in €/kg. If the price indication in PLE is applied only on filling station totem, the legal framework needs to be changed.

The model could be introduced by implementing Art. 7 para. 3 of the Alternative Fuels Infrastructure Directive 2014/94/EU and in this process, if legally additionally necessary, initiate an addition to Article 3 of the Price Indication Directive 98/6/EC, which should incorporate the next paragraph: *When displaying fuel prices on a filling station totem, for natural gas the unit price per "1 petrol litre equivalent" may be used.*

On the other hand, if all price indications in €/PLE from the filling station totem to the billing price is implemented, it would require significant adjustments in calibration and unit law.

### 3.3.2 Evaluation

Some quite relevant activity has been carried on during 2016 in this context, inside the STF (Sustainable Transport Forum - Workshop on Fuel Price Comparison). A special event has been held to discuss the matter. The European Commission, DG MOVE C1 - Clean Transport and Sustainable Urban Mobility organized the Workshop on Fuel Price Comparison in October 2016. It dealt with the measures aimed at the implementation of Article 7 paragraph 3 of the Directive 2014/94/EU on the deployment of alternative fuels infrastructure: fuel price comparison.

In the Workshop, the following methods for fuel price comparison were examined and evaluated:

- Option 1: Cost per 100 km
- Option 2: Cost reflected in energy content of the fuel (Petrol litre equivalent price)
- Option 3: Conventional display of fuels' prices with additional indication of energy content
- Option 4: Petrol litre equivalent per 100 km for each fuel

For the values to be used to determine energy fuel content and engine efficiency, two options were under discussion:

- Option 1: Use of the values for the energy content of fuels and efficiency of specific engine type as indicated in the Clean Vehicle Directive, JEC Study on TTW + other sources
- Option 2: Each Member State defines the energy content of the fuels used in its territory and identifies the efficiency of specific engine types

On how to determine the price of fuels in conventional units, two options were considered by the workshop team:

- Option 1: Prices to be defined by retailers on real basis
- Option 2: Prices to be determined by Member States on the basis of the average prices on the last quarter of the year

The workshop team also discussed on how to display prices; options under consideration:

- Option 1: prices displayed at totem level
- Option 2: prices displayed at totem, pump and receipt
- Additional measure: prices displayed via the internet

This is a rather complex but important item. The new harmonized system to display the price of fuels at the pump should be developed in such a way that it ensures the highest possible degree of transparency while it avoids confusing the consumer and hence should opt for a price comparison unit that is already familiar. A good way to compare fuels would be based on their specific energy content, expressed e.g. in kWh, which is a SI unit, meaning universally understood and accepted; or MJ. It can be done in a pragmatic way by referencing to official documents, e.g. the Directive 2009/33/EC for the promotion of clean vehicles, which indicate net heating power of fuels, valid for all Europe.

On February 2017 CEN published a document (CEN reference: BT N 10662) where four different fuel price approaches were analysed also regarding Art 7.3 AFI Directive "Where appropriate, when displaying fuel prices at a fuel station, in particular for natural gas and hydrogen, comparison between the relevant unit prices shall be displayed for information purposes".

In this document, not only four different approaches are examined (in line with Sustainable Transport Forum - Workshop on Fuel Price Comparison) but also the comparison between the methods is provided:

Option 1a based on:

- Energy content of the fuels (MJ/litre) and
- Energy efficiency of the engine (TTW in MJ/100 km)

$$Price\ of\ the\ fuel\ \left(\frac{€}{sales\ unit}\right) x \left(\frac{Energy\ Efficiency\ TTW\ \left(\frac{MJ}{100\ km}\right)}{Energy\ content\ \left(\frac{MJ}{sales\ unit}\right)}\right) = Price\ per\ 100\ km$$

Option 1b based on:

- The method is based on the fuel consumption per 100 km as indicated by the manufacturer.

$$Fuel\ price\ x\ Fuel\ consumption\ per\ 100\ km = \ Price\ per\ 100\ km$$

Option 2 based on:

- Petrol litre equivalent (kwh could also be used as unit)
- Based on energy content of motor fuels as mentioned in the annex of 2009/33/EC Directive

Option 3 based on:

- The use of dual display
- Fuels are displayed in the conventional way
- In addition, a further indicator of energy content in mega joule per sales unit is displayed

In Table 1, a comparison between the methods above mentioned are described:

*Table 1. Comparison between methods. Advantages and disadvantages*

| Method | Advantages | Disadvantages |
|---|---|---|
| Option 1a | The higher efficiency, in particular of electric vehicles, is considered. | The values on Energy efficiency from the JE study are contested |
| Option 1b | Real values on the basis of manufacturer information | The information could only displayed, as indicative prices, for specific and similar model of vehicles |
| Option 2 | The comparison is done on real values accepted by all stakeholders. The information can be displayed in the totem as well as in panels, monitors… | Energy efficiency is not considered. This create a disadvantage to electric vehicles. |
| Option 3 | Real values are provided. However, the information for consumers is very limited. | Its use can create confusion to the consumers (e.g. the use of MJ as unit). |

This CEN document also includes information about the status of the *Standardization Work on Fuel Labelling – EN 16942*:

DG ENER provided feedback on the finalized standardization work in CEN on fuel labelling. Standard EN 16942 "*Fuels - Identification of vehicle compatibility - Graphical expression for consumer information*" was made available on 12 October 2016. It was suggested by several stakeholders that the Commission should create a coordination group of interested stakeholders to accompany the implementation process.

CEN explained that TC 441 developed the standard, and offered that TC 441 itself be the platform to accompany the implementation. In addition, TC 301 was planning to discuss on 17 January 2017 the proposal for EU labelling, as EN 16942 is not complete and work will be finalised during 2017. DG ENER confirmed that there is still work to be done and stated that a harmonised information note to national authorities and national standardisation bodies is the minimum. Stakeholders insisted that the Commission should coordinate this exercise in order to avoid confusion.

## 3.4 Separation distances

Safety distances to objects (such as buildings) outside of the station as well as components inside the station including the refuelling truck are required.

PGS 33-1 *Natural gas – Liquefied natural gas (LNG) delivery installations* and ISO 16924 *Natural gas fuelling stations – LNG stations for fuelling vehicles,* set out internal and external safety distances.

Safety distances in ISO 16924 were based on PGS 33-1, but most of them were refused or modified by the working group.

### 3.4.1 Proposal in Deliverable 4.4

Safety distances and scenarios according to PGS 33-1 are shown in Deliverable 4.4.

ISO 16924 focuses on external distances (depending on the storage capacity) and distances between LNG storage tanks, also deeply explained in Deliverable 4.4

### 3.4.2 Evaluation

*ISO 16924:2016 Natural gas fuelling stations — LNG stations for fuelling vehicles* has provisions relevant to separation distances:

- Annex B (normative) Separation distances:

In case of the aboveground LNG equipment, the separation distances between the LNG storage tank, the LNG transfer point, the site boundary, building, storage of other flammable liquids and gases and other equipment of the refuelling station must be sufficient to limit the potential for escalation of an LNG related incident to adjacent activity and vice versa.

The separation distances are applicable if the buildings are outside the zones. Separation distances can be reduced if a fire wall is constructed. That fire wall must be of at least one hour fire-resistant construction. The fire wall must not restrict access of fire fighters and their equipment.

*Table 2. Separation distances from buildings of stationary LNG fuelling installations (abstract)*

| Persons in the building | Additional comment | Onsite buildings Min. distance m | Offsite buildings Min. distance m |
|---|---|---|---|
| Distance from LNG storage and other components containing LNG | | | |
| None | | 0 - 3 | 3 |
| <10 | | 10 | 15 |
| 10 – 100 | | 15 | 30 |
| >100 | | 15 | 30 |
| Distance from offload connection | | | |
| None | Buildings with non-combustible walls | 0 - 3 | 3 |
| <10 | Buildings with combustible walls | 10 | 10 |
| | With ground pump | 10 | 10 |
| | Without ground pump | 20 | 20 |
| 10 – 100 | | 30 | 30 |
| >100 | | 50 | 50 |
| None | Buildings with non-combustible walls | 0 - 3 | 3 |
| | Buildings with combustible walls | 10 | 10 |

*Table 3. Internal separation distances of stationary LNG fuelling installations (abstract)*

| Type of internal distance | Min. distance m |
|---|---|
| Offloading connection – outer shell of the LNG tank | 6 |
| ↑ If a fire protection wall or other fire resistant shield is installed or if the LNG storage tank has 1 hour fire resistance at a radiation of 15 kW/m$^2$ | 0.5 ÷ 6 |
| Fuelling vehicle – outer shell of LNG tank | 4 |
| Onsite tank for flammable liquids and their gas vent – outer shell of the LNG tank | 5 |
| ↓ Boundary limit – outer shell of the LNG tank: | |
| - LNG tanks <120 m$^3$ | 3 |
| - LNG tanks <120 – 300 m$^3$ | 6 |
| - LNG tanks >300 m$^3$ | 10 |
| Boundary limit - LNG tank offloading connection | 3 |
| Overhead electric lines, > 600 V | 10 |
| Onsite tank for flammable liquids and their gas vent – LNG tank offloading connection | 5 |
| Dispenser – onsite building | 6 |
| ↑ If "dead-man button" limits the accidental discharge of LNG to 60 s | 3 |
| Distance between LNG tanks | 1.5 |

*Table 4. Separation distances in case of underground LNG tank*

| LNG storage tank water capacity<br>$m^3$ | Min. distance from buildings and the adjoining property line that can be built upon m | Min. distance between LNG storage tanks<br>m |
|---|---|---|
| <10 | 4.5 | 4.5 |
| 10 - 120 | 7.5 | 4.5 |
| >120 | 15 | 4.5 |

Buried and underground LNG storage tanks must be suitable to prevent the 0°C isotherm from penetrating the soil.

*ISO 16923:2016 Natural gas fuelling stations — CNG stations for fuelling vehicles* has provisions relevant to separation distances as well:

- Annex B (normative) Separation distances:

Annex B defines separation distances as the minimum separation between a hazard source (an installation component with a hazardous substance) and the potentially affected object of the hazard (a person, vulnerable installation component or building within the establishment).

It must prevent or limit the harmful effect as a result of a foreseeable incident and hence prevent either an escalation to a bigger incident (domino effect) in the case of internal separation distances or effects to external objects in the case of external separation distances.

A foreseeable incident in one installation component could not lead to the (partial) failure of another installation component. An internal separation distance therefore prevents a relatively small incident developing into a big incident. Adequate internal separation distances are hence a condition for safe execution of the CNG delivery installation.

An important prescription of ISO 16923:2016 in this respect is that the external separation distances of a CNG refuelling station are not required to exceed those for other liquid fuels.

*Table 5. Internal separation distances*

| Total site storage below 10,000 litres | | |
|---|---|---|
| Hazard source | Dispenser | Storage cylinders and compressor |
| Buildings openings(non-combustible) | > 3 m | > 3 m |
| Building walls | ≥ 0 m | > 1 m |
| Facility perimeter | > 5 m | > 5 m (> 10 m for storage >10.000 l) |

If a 2 hour fire wall is built between CNG equipment and the property line the separation distance may be reduced to 1 m. The fire wall must have a minimum height equal to 0.5 metres greater than the maximum height of the equipment and must limit the hazardous zone from crossing the property line.

## 3.5 Venting of natural gas

Fuelling station design and the proper operation of stations and vehicles to minimize losses to atmosphere are critical to maintain the economic and environmental benefits of natural gas. To mitigate venting, the station should be designed and operated so that no vapour is released to the atmosphere and that any excess vapour is recovered and used.

It is not economically feasible to install equipment to recover and re-liquefy boil-off vapours, so the fuel has to be used within two weeks. In stations with high utilization rates, however, the very act of refilling the storage tanks can have the effect of re-condensing methane in the gas state, thereby improving the pressure time characteristics of storage. Additionally, for stations with mixed dispensing of both LNG and CNG, any boil-off methane could be captured and injected into the CNG distribution intake stream.

### 3.5.1 Proposal in Deliverable 4.4

Stations must not vent to atmosphere in normal conditions. If a vehicle tank needs its pressure balanced to allow a fill to take place, where safety is not a concern for whatever reason, any free gas is passed back to the storage tanks or to a CNG system. In normal operation, the balance line is not connected as the cold LNG and the pump can overcome the typical operating pressures found in vehicle tanks.

Boil-off gas from other parts of the station may be returned to the storage tank for accumulation and/or treated in other suitable ways.

In the case of emergency, venting of boil-off gas directly to the atmosphere is permitted provided that it is vented in a safe manner to a safe location, for example through a vent stack.

### 3.5.2 Evaluation

In the section 3 "Terms and definitions" of *ISO 16924:2016 Natural gas fuelling stations — LNG stations for fuelling vehicles*, it is defined the vent stack; i.e. the pipe that allows gas to be vented at a safe elevation and location.

The section 6 "General design requirements" gives prescriptions for Prevention of venting of natural gas. The design and operation of the fuelling station must minimize the venting of boil-off gas to the atmosphere. During normal operation, venting should be limited to minor releases of gas resulting, for example, from disconnection of hoses. The Boil-off gas from the other parts of the refuelling station may be returned to the LNG storage tank for accumulation and/or treated in other suitable ways. In the case of emergency, venting of boil-off gas to the atmosphere is permitted provided that it is vented in a safe manner to a safe location. During maintenance, repairs or refurbishment, and purging of equipment, venting of methane to atmosphere should be minimized regarding quantity and flowrate for prevention of explosive atmospheres in surrounding.

At section 7 "Fuel supply to the refuelling station" this item is covered. Venting of the LNG storage tank during filling can be done only under emergency conditions and in a manner acceptable to local authorities. Bleed or vent connections must be provided so that loading arms and hoses can be drained and depressurized prior to disconnection if necessary. The connections must relieve to the vent stack.

Section 8 "Storage" covers venting in many respects. The vent stack must be designed to prevent entry of rain and snow. The drainage at the bottom of the vent stack should be considered to allow removal of potentially trapped atmospheric condensates. Additional refuelling station vent lines to the LNG storage tank vent stack are permitted, provided that the gas from these lines is dry and that the stack can adequately handle the extra venting capacity without compromising the operation of any interconnected relief devices due to excessive backpressure.

Any try cock that opens to the atmosphere must not be any routine tool used at every filling of the LNG storage tank. The maximum allowable working pressure of the LNG storage tank should be reasonably higher than the larger of the boiling pressure of LNG (saturation) at delivery; or the pressure to which LNG is saturated as required for operation; and still having a reasonable holding time that allows reasonably long non-venting operation.

The storage tank must be equipped with at least two relief valves, connected to the top of the inner vessel. They must comply with ISO 21013-1. Each pressure relief valve must discharge to open atmosphere. Where discharge of gas to the atmosphere is considered unsafe, the relief valve vent line is to be headed to a vent stack, which enables safe discharge to atmosphere.

About depressurization, for decreasing the pressure in the LNG storage tank, a manual or automatic venting system must be provided (e.g. for venting into low pressure pipeline) unless the over pressurization of the LNG storage tank is prevented by other means. The pressure relief devices installed on the LNG storage tank must not be used for venting the boil-off gas as a routine way of operation.

All buried LNG storage tanks must be equipped with access to all the tank equipment on the outside of the outer tank. The relief vent stack and the vacuum relief device vent must be safely piped to the aboveground area.

Section 9 "Pumps and compressors". Any vapour, generated by cool down, operation and cold standby, from degassing line of the pump must be collected to the LNG storage tank or somewhere else to prevent venting to the atmosphere.

The system instrumentation and accessories required for safe operation of pumps include a high pressure venting cryogenic valve (manual or/and automatic), when required by the design of the pump. Possible venting must be maintained with respect to the requirements of the standard.

Section 10 "Dispenser". About venting this section reads that the hose design and installation must include precautions for return of the liquid accumulated in the fuelling hose and the vaporised gas back to the LNG storage. The heat leak rate, pressurization and hydrostatic height aspects of such a system must be taken into account.

Section 13 "Pipework". The vent lines for wet streams must not be connected to vent systems and vent stacks for dry cryogenic gas streams.

Also Annex H (informative) "Recommendations for centrifugal pumps design" deals with venting. The pump shaft protruding through the pump housing should be adequately sealed by a dynamic seal, to prevent or to minimize any gas leakages.

## 3.6 LNG nozzles and receptacles

Unlike chapter 2.2 Couplings and receptacles, this point deals with the existing gap between the tanker and the station connection. Even though there are proposed designs for the vehicle to be refuelled nozzle and the station connector, there is not a standardized design between the tanker and the station for refuelling the station.

### 3.6.1 Proposal in Deliverable 4.4

Connection between the LNG tanker and the tank at the filling station is only a question between the owner of the filling station and the supplier. Operatively every LNG plant and supplier requires individual loading procedures. There is not a European standard or regulation in this regard. However, in terms of supply security, it would be necessary that the connections are always compatible with each other.

### 3.6.2 Evaluation

ISO 16924 in paragraph 6 “LNG supply interface” states the requirements of safe LNG delivery to the station from the LNG tanker and the protection against over pressurization and overfill of the LNG storage tank, but does not fix the design of the LNG receptacle and LNG nozzle to be used in this operation.

To guarantee the interoperability between LNG tankers and LNG stations, the standard for the nozzle and the connector for the operation of refilling the LNG tank of the station shall be defined.

## 3.7 Operation

Fuelling infrastructure operations covers the following topics: shutting off the vehicle, grounding the vehicle, ensuring that vehicle is not moved with the fuel hose connected to the vehicle, fuel connector operation, fuel connector spillage, cold metal contact and required personal safety aspects in the refuelling operation of LNG vehicles.

### 3.7.1 Proposal in Deliverable 4.4

Driver training is highly recommended in order to cover the principal issues. Nowadays this training is carried out in a local environment since there is not a common recommendation document in this regard. In any case, it must make sure the information in each market contains all relevant topics.

The most important aspects to cover in a future and harmonized recommendation are described in Deliverable 4.4

### 3.7.2 Evaluation

SAE J2343 asks the vehicle manufacturer to create a vehicle operation manual related to LNG safety, the minimum content is:

- LNG safety
    - Chemical and Physical Properties
    - Safety Hazards
    - Protective Equipment
    - First Aid and Emergency Services
- Fuel System Overview
    - Fuel Tank System
    - Vaporizer
    - Pressure Relief Devices
    - Automatic and Manual Shutoff Devices
    - Vent Stack
- Operational Safety
    - Pre- and Post-Operational Safety
    - Low-Temperature Warning
    - Methane Detection
- Fuelling Safety
    - Fuelling Procedure
    - Grounding
    - Dust Caps
    - Tank Fuelling with Venting Required
        - Tank Venting
- Fuel Quality
    - Fuel Specification
    - Fuel Contamination
    - Use of CNG
    - Weathering of LNG Fuel
- Indoor Parking Safety
    - Short-Term Parking
    - Long-Term Parking

It should be compulsory for the European vehicle manufacturers to create this manual to be given to the vehicle operators and vehicle drivers. Safety when operating a LNG vehicle should be the main goal for all actors, not only for safety but also to extend the idea that LNG is a safe and a convenient technology.

Regulation 110 has an important role on that and could be amended to contain the requirements for creating these safety operation manuals.

## 3.8 Maintenance facilities

There are a number of special requirements that should apply to workshops servicing LNG or CNG vehicles. The recommendation is that consideration is given to the revision of ECE R115 to document these requirements. This may include the provision of regulations covering external safe areas of work for the drain down of LNG containment, and the inclusion of methane detection in roof areas of workshops, which is the obvious mitigation to any risk assessment which any company might carry out.

The specific requirements for NGV workshops are presented on issues related to ventilation, electrical installations on the roof and temperature of heaters exposed surfaces. It specifically indicates that in the case of LNG vehicle repairs, the use of open flame heaters or heating equipment is not allowed with surfaces exposed to a temperature higher than 399°C.

If the only available facility for maintenance work is not specially equipped for NGVs, work should be done outdoors.

### 3.8.1 Proposal in Deliverable 4.4

Proposed requirements for maintenance facilities are focused on heating/cooling systems and gas detectors.

### 3.8.2 Evaluation

Even though the situation has not changed regarding Deliverable 4.4, some countries have created their own regulations concerning workshop requirements/maintenance.

As an example, Spain has proposed a national regulation: *UNE 60637:2011 "Workshop for the installation and repair of vehicles using compressed natural gas: Premises, personnel, procedure and equipment requirements"*. This regulation contains requirements for the workshop and about staff operation as follows:

Workshop:

- Requirements for the general areas where no CNG work is carried out
- Building and installation requirements for the area in which CNG work is carried out
- Accessibility, safety and health
- Periodical inspections

Staff:

- CNG Vehicle reception
- Work at high pressure vehicle circuits
- Work at low pressure vehicle circuits
- Paint and sheet metal work
- Retrofit kit and accessories installation
- Verifications
- Delivery of the vehicle

This standard should be amended to include LNG vehicles maintenance operations so additional building requirements and working procedures adapted to LNG operation should be added.

As final conclusion, all European countries should have harmonized regulations concerning workshop requirements/maintenance.

CEN/TC 326 edited in the past the norm EN 13423:2000 "Compressed natural gas vehicle operations". The norm provides guidance on the operation of vehicles that use natural gas as a fuel, and gives recommendations of good practice for users, parking facilities, refuelling stations and workshops appropriate for NGVs, whether or not the gas system is to be worked on.

In CEN/TC 326, the WG 3 is now revising and implementing this norm, which is quite old.

Also in CEN/TC 326, the WG 5 is responsible for editing a similar norm for LNG vehicle use and operations. This is a totally new norm, and it will be harmonised to the maximum possible extent to that for CNG vehicles.

## 3.9 Parking structures

This section of the document discusses issues related to parking structures receiving LNG vehicles and other restrictions when LNG vehicles circulate in other particular areas.

### 3.9.1 Use of underground public parking

While there is no common Europe-wide regulation on LNG or other gas vehicles regarding the use of underground car parks, there are some regulations at the national level (mentioned in Deliverable 4.4).

As the gas could be expelled into the air through the vent on the cryogenic tanks; there is the possibility for the natural gas to be burnt accidentally, so the LNG trucks should be parked far from fire sources, inflammables and explosives. It is better to avoid closed areas for parking LNG trucks for long periods, as the gas vented from the cryogenic tanks does not dissipate easily, if the gas/air mixing rate reaches critical levels, it could explode. An open area is a better place for long-term parking.

It is recommended to inform the security staff about the gas venting phenomenon, in order to avoid any incident.

#### 3.9.1.1 Proposal in Deliverable 4.4

The following proposals for underground garages were suggested:

- Installation of methane leak detectors or justification that the ventilation system is good enough to vent out any possible methane emissions.
- Piping of the relief stack outside the building structure.

### 3.9.2 Long-time parking conditions

#### 3.9.2.1 Proposal in Deliverable 4.4

The venting policy could be controlled creating a mandatory obligation for LNG vehicle operators to de-fuel their system when parking for a period longer than the holding time (5 days). It would be necessary to develop an inerting system.

The utilization of liquid nitrogen as back-up, helping to keep the tank cold would decrease the boil-off phenomena in LNG fuel tanks.

### 3.9.3 Other restrictions

When a natural gas vehicle is to be transported by road, rail or ferry, or a tunnel is to be used, it should be checked whether there are any specific restrictions.

### 3.9.4 Evaluation

The vehicle operation manual that SAE J2343 asks for, should contain information about the parking of the LNG vehicle taking into account if the parking is a short-term parking or long term-parking

It is necessary to define the equipment used to recover gas from LNG tanks prior the long-term parking and how this gas could be transferred to the domestic gas grid or other options.

## 3.10 Compliance with measures

Currently the measurement of the dispensed LNG is less than optimised at the point of refuelling a vehicle. Compliance to weights and measures standards needs to be facilitated by the inclusion of LNG within these regulations.

It is still common for gas to be vented back from a vehicle tank to the station at point of refuelling. Many LNG stations do not deduct this gas from the amount of LNG delivered to the truck. So, vented gas is not adequately measured and systems do not always therefore correctly advise operators of the correct amount of gas consumed by the truck. This affects the fuel economy statistics that are calculated to monitor fuel efficiency. At the same time, it is not possible to know the gas quality.

Anyway, this potentially overcharges the truck operator for gas which has been taken from a truck back to the station. All of these losses are currently costed against the operating costs of the truck which negatively affects the business case for the adoption of LNG-powered trucks and may influence take up on a wide scale.

### 3.10.1 Proposal in Deliverable 4.4

It is proposed to include a mandatory and adequate measure system for gas that is vented back from a vehicle to the station when refuelling with the objective of properly informing the operator about the correct amount of natural gas consumed by the truck.

The issue regarding who assumes these overcharges, and in which proportion, needs further development.

### 3.10.2 Evaluation

This proposed system to measure the quantity of gas transferred to the LNG station when the LNG tank is vented, should be also able to measure certain parameters in order to stablish the quality of the vented gas recovered by the LNG station.

If it was mandatory for the refuelling station to pay for this recovered gas from the over pressured/overheated LNG tank, then it would be necessary to determine if it is reliable and cost effective to include in the LNG station natural gas analysers.

According to the project stake holders, recovering the vent gas from the truck tank can be seen as an additional service offered to the truck operator (and to the environment); in this case, the value of the recovered gas should be maybe seen as a “payment” asked to the truck operator, rather than a “penalty” imposed to the station owner.

# 4 Conclusions

When the LNG Blue Corridors FP7 Project started, the regulatory framework related to LNG was not fully developed. Many working groups were working in order to develop the standards and regulations needed to certify the refuelling stations and approve the vehicles. Thanks to this initial work, this situation has changed and nowadays LNG technology is mature and can be approved and certified.

The publication and entrance in force of UN Regulation 110.01 in 2013 has been one of the key items for the success of the project since it opens the possibility to register vehicles using LNG as a fuel throughout Europe.

UN Regulation 110.01 was created amending the original UN Regulation 110.00 that only covered CNG vehicles. The amendments were done using mainly parts of what later became the ISO 12614:2014 and part of the ISO 12617:2015.

Furthermore, ISO standards that were initially in preparation have developed all the requirements to be fulfilled by the LNG Refuelling Stations (*ISO 16924:2016 Natural gas fuelling stations - LNG stations for fuelling vehicles*). Although this standard publication has arrived almost at the end of the project, it will be the base for the future development of LNG Refuelling Stations.

This group of standards and UN Regulations allowed the LNG Blue Corridors Project to evolve from a stage where the approval of vehicles and the design and legalization of LNG Refuelling Stations was done using national standards to a final stage in which the registration of OEM vehicles is done using UN Regulations.

The use of common standards and regulations guarantee the safe use and the compatibility of the LNG vehicles and the LNG Refuelling Stations around Europe.

However, a lot of work is still remaining to be done in the field of certification - standardization and some technological aspects should be improved.

One of the main aspects to be treated in the standards and regulations in development should be the information in the LNG supply system to the engine performance, operation, refuelling and maintenance safety. This safety information should be prepared by the vehicle and vehicle component manufacturers, as well as the component for refuelling stations and Refuelling Station manufacturers. SAE J2343 requests to create similar information but this standard is not in force in Europe. Similar/equivalent norms are anyway under development in CEN.

Described below are some comments related to topics that need to be improved in LNG vehicles in the future:

- Venting system and Strategies for reusing in the vehicle the recovered boil-off gas from the tank

UN Regulation 110.02 and SAE J2343 clearly specify a hold time of not more than 5 days without venting for a LNG full tank. UN Regulation 110.02 allows venting in case of overpressures (boil-off) and SAE J2343 asks to avoid boil-off emissions. Even though there are no proposals or procedures to avoid these gas emissions, they should be created and more investigation in possible systems or procedures to reduce gas emissions should be started.

The natural gas vented recovering systems developed to be installed on vehicles should be reliable, cost effective and should not increase the mass of the vehicle (it is a critical factor). If it is not possible to develop such kind of systems, then parking areas destined to long-term parking of LNG vehicles and workshops for maintenance should be equipped with systems to recover the boil-off gas vented.

- Couplings and receptacles

UN Regulation 110.02 and ISO 16924 have defined the requirements for the refuelling nozzle and the refuelling connector (now they are compatible). Work regarding the compatibility between existing LNG vehicles and refuelling stations should be started.

Once the development of the ISO NP 21104 for a new refuelling nozzle is finished, a compatible refuelling connector should be created for the refuelling stations. The unification work should be repeated in the future in order to guarantee the compatibility between LNG vehicles and Refuelling Stations.

- Type approval of dual fuel retrofit systems at Euro VI

The UN Regulation No 143 on uniform provisions concerning the approval of Heavy Duty Dual-Fuel Engine Retrofit Systems (HDDF-ERS) to be installed on heavy duty diesel engines and vehicles (ECE/TRANS/WP.29/2016/110), which is in force since June 2017, does not apply to the retrofit of existing Euro VI vehicles.

Postures from different European countries are not the same regarding the retrofit system. Even though lots of expectation was generated, there is not a clear agreement between countries.

This UN Regulation has to cover the existing gap in the approval of retrofit systems to convert diesel heavy duty vehicles to dual-fuel operation with LPG, CNG and/or LNG components.

This new regulation does not affect the Blue Corridors project, as the participant vehicles are mainly equipped with dedicated engines, but have an effect in the approval of the conversion of such kind of vehicles, that up to now have been done only according to national prescriptions or standards.

Market needs this retrofit option to be available to help to spread the LNG use in transport. This kind of vehicles should be in the scope of this new UN Regulation and the necessary new requirements should be introduced.

- Weights and dimensions for LNG vehicles

Council Directive 96/53/EC has been amended by Directive (EU) 2015/719 and it is allowed to increase the maximum authorized weights in international traffic up to one ton (there is no modification in the maximum authorized weights per axle).

The possibility to increase the maximum authorized weight per axle in some vehicles should be studied. This would help to fix the problem that some manufacturers have regarding the overweight of a single axle due to the position of the LNG tank.

- Tunnel restrictions

Tunnel restrictions should be limited to some special cases to allow the free circulation of LNG transport vehicles. Procedures should be created to safely manage broken LNG vehicles or vehicles involved in small accidents. Equip the tunnel for firefighting and provide extra ventilation, gastight electrical systems and natural gas sensors installed in the tunnel could also improve safety and reduce tunnel limitations.

Described below are some comments related to topics that need to be improved in LNG Refuelling Stations in the future:

- Refuelling pressure and temperature

Refuelling pressure is not harmonized in Europe, there are no limitations in any regulation (main delivery pressure is 800 kPa but there are some special cases).

Trucks work at 800 kPa and the tendency in the future should be to reduce the pressure which will increase the vehicle range due to fuel density. In addition, lower pressures will increase pressure margin and will help to minimize potential venting through the pressure relief valve.

Pump assisted natural gas systems can operate at very low pressures in the LNG tank but at high pressure in the engine injection system. It is strongly recommended to reduce the maximum pressure of the vehicle LNG tanks so that the LNG stations should not need pumps. This will make the refuelling station systems cheaper.

- Consumer information about LNG price

This is a rather complex but important item. The new harmonized system to display the price of fuels at the pump should be developed in such a way that it ensures the highest possible degree of transparency while it avoids confusing the consumer and hence should opt for a price comparison unit that is already familiar. A good way to compare fuels would be based on their specific energy content, expressed e.g. in kWh or MJ

CEN is working in different options to inform users about the LNG price, an agreement on the final option to be applied should be reached and applied as soon as possible.

- Venting of natural gas

Refuelling station design and the proper operation procedures of stations and vehicles to minimize natural gas losses to atmosphere during refilling operations are critical to maintain the economic and environmental benefits of natural gas. To avoid venting, the Refuelling Station should be designed and operated so that no methane vapour is released to the atmosphere and that any excess methane vapour is recovered and used. Any boil-off methane vapour in the LNG vehicle tank should be captured and processed in the Station. All of the boil-off methane vapour should be used in the CNG refilling system (LCNG stations) or injected to the CNG domestic distribution system (if available)

ISO 16924:2016 gives prescriptions to design the Refuelling Station so that the methane emissions during operation are reduced to a minimum.

- LNG nozzles and receptacles

ISO 16924 in paragraph 6 "LNG supply interface" states the requirements of safe LNG delivery to the station from the LNG tanker, but does not fix the design of the LNG receptacle and LNG nozzle to be used in this operation.

To guarantee the interoperability between LNG tankers and LNG stations, the standard for the nozzle and the connector should be defined.

- Operation

SAE J2343 requests to vehicle manufacturers to create operation manuals covering critical aspects about safety during operation, refuelling, maintenance, long term parking... UN Regulation 110 has no prescriptions on that and should be amended so as to request for this manuals in Europe.

CEN/TC 326 WG 5 is working on this scope, also including the following two items (maintenance facility and parking structures).

- Maintenance facilities

Maintenance facilities and the people involved in activities related to LNG vehicles should have the appropriate safety equipment and procedures. LNG vehicle tanks should be depleted and inertized prior to maintenance operations.

There is not a harmonized European Regulatory framework that certifies neither the correct maintenance of LNG workshops nor their staff operation. Some countries have developed their own regulation taking care of these issues, however, these minimum requirements should be addressed as soon as possible in future regulation.

- Parking structures

There are no harmonized prescriptions on how the parking areas should be designed and equipped to allow safe parking of LNG vehicles.

In case of long term parking, the vented gas could be expelled into the air through the tank venting system. The vented gas could be accidentally burnt so it is recommended to park LNG vehicles far from fire sources, inflammables and explosives. It is also recommended to avoid closed areas for long term parking periods.

Parking areas for LNG vehicles should be properly indicated and equipped with the necessary tools to manage/dispose the vented gas with safety. These prescriptions should be in line with the ones applicable to workshop maintenance.

To sum up, thanks to the continuous work of vehicle and component manufacturers, researchers and other standardization organizations, standards and regulations have been developed to allow the LNG technology to progress. These standards and regulations are expected to fill the gaps already existing in the actual collection of technical solutions and regulatory framework.

LNG Blue Corridors project has proved that from the technical and regulatory point of view, long distance transport activities using LNG trucks are a reality.

It is expected that LNG technology will be spread to all Europe so as to reduce the dependence on non-renewable fossil fuels, maintaining the transport capacity needs and not increasing the air pollution levels. Natural gas technology will be a bridge to future greener technologies.

# References

## List of Tables



## List of Figures