Economic Commission for Europe

Inland Transport Committee

Working Party on the Transport of Dangerous Goods

Ninety-fifth session **8 November 2013**
Geneva, 4–8 November 2013

LNG: A safe fuel for trucks

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kiwa
Partner for progress

LNG task force

Contents of this presentation

- Overview standards and regulations current present and upcoming
- LNG system and its components
- LNG tank and components
- What is boil off?
- Venting management system
- Comparison between diesel and methane
- Crash and fire accidents
- Fire instructions
- Safety tests required on LNG tank and components

Where does the LNG vehicle regulation comply with

- **LNG Task force:**

  responsible for updating the regulation 110

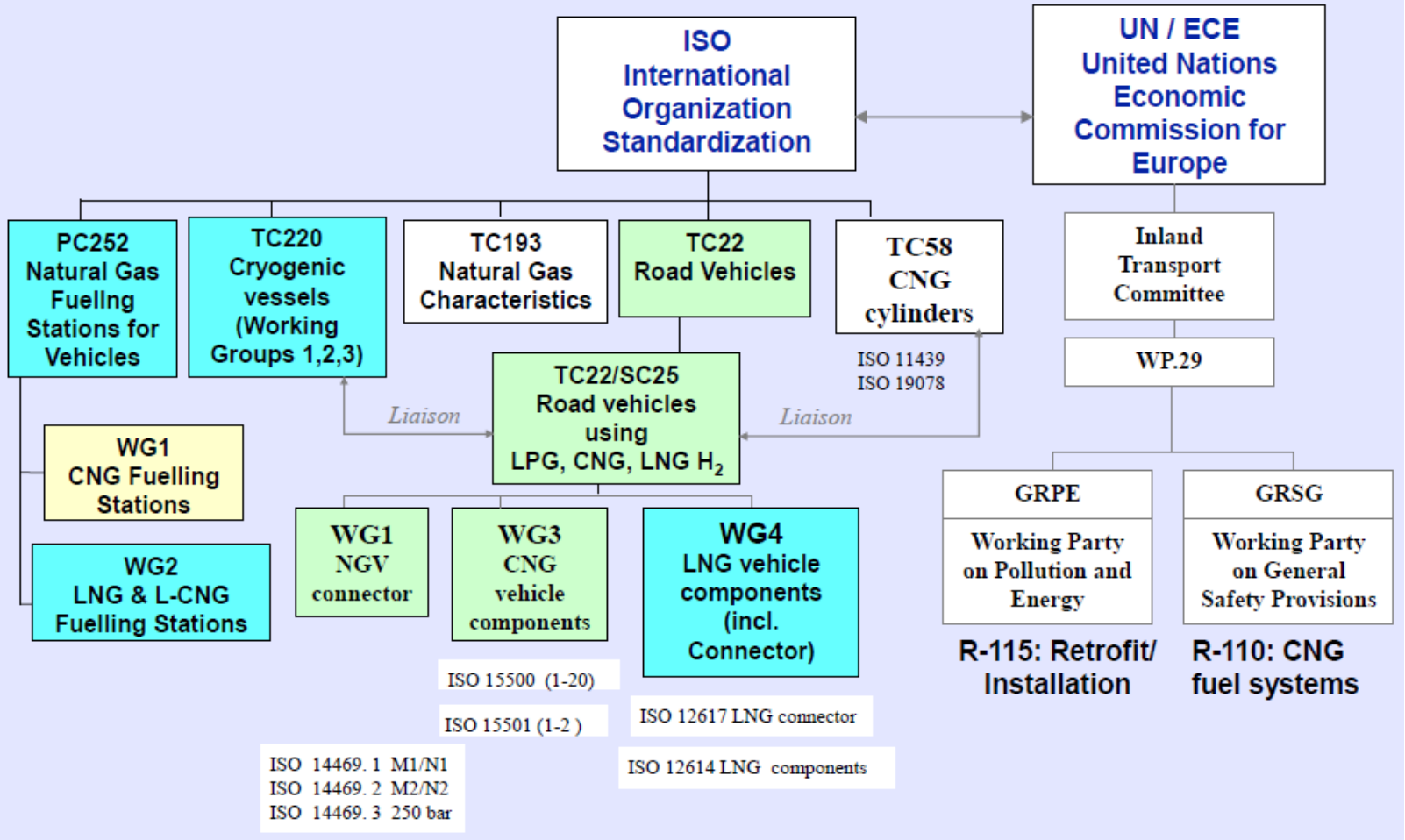
  - Members of the LNG TF (component manufacturers, NGVA Europe, NGV Global, OEM's and testing agencies)

- **Regulation 110** Uniform provisions concerning the approval of:

I. Specific components of motor vehicles using compressed natural gas (CNG) and/or liquefied natural gas (LNG) in their propulsion system;

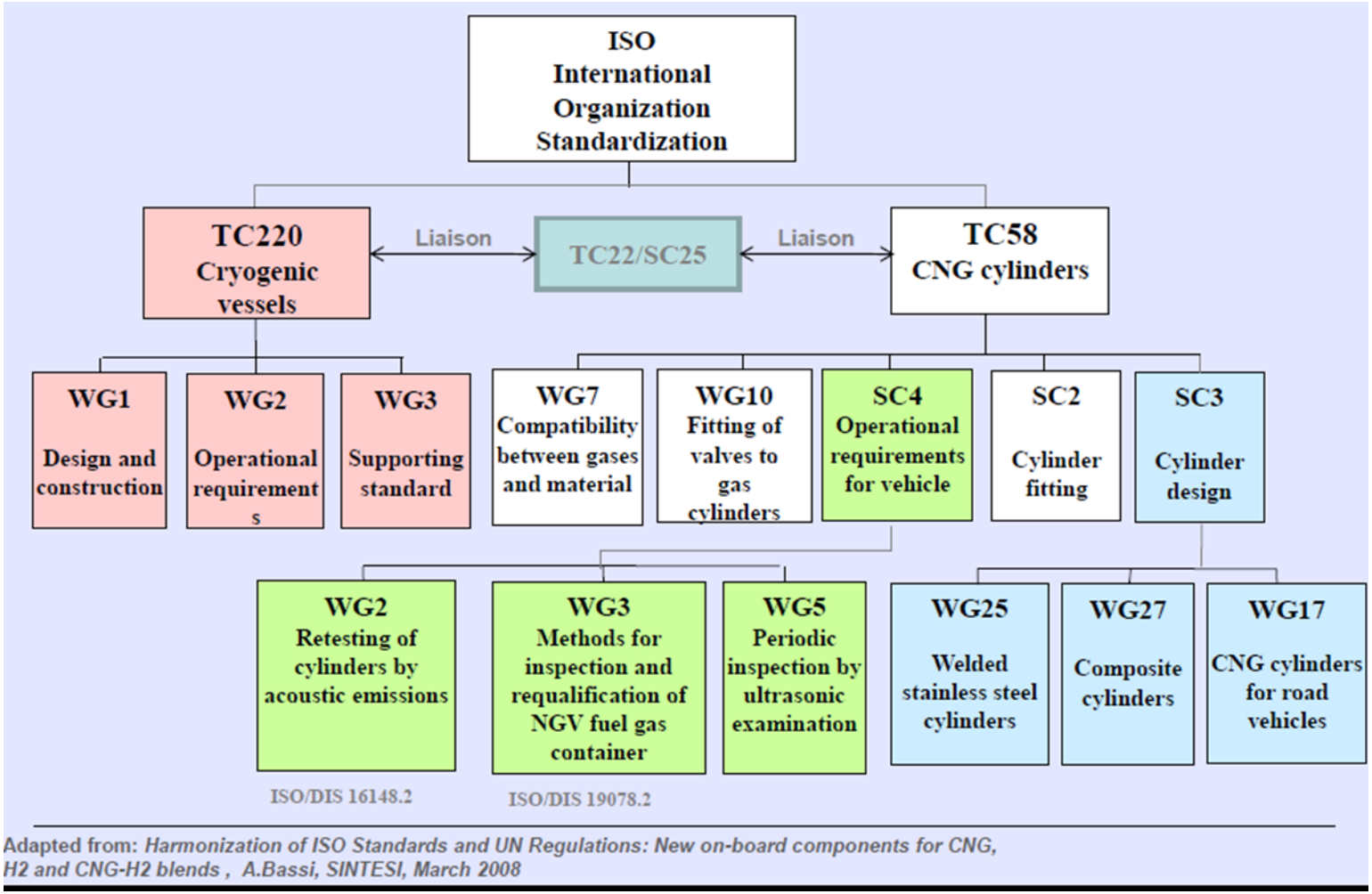
II. Vehicles with regard to the installation of specific components of an approved type for the use of compressed natural gas (CNG) and/or liquefied natural gas (LNG) in their propulsion system

ISO STANDARDS– LNG FOCUS



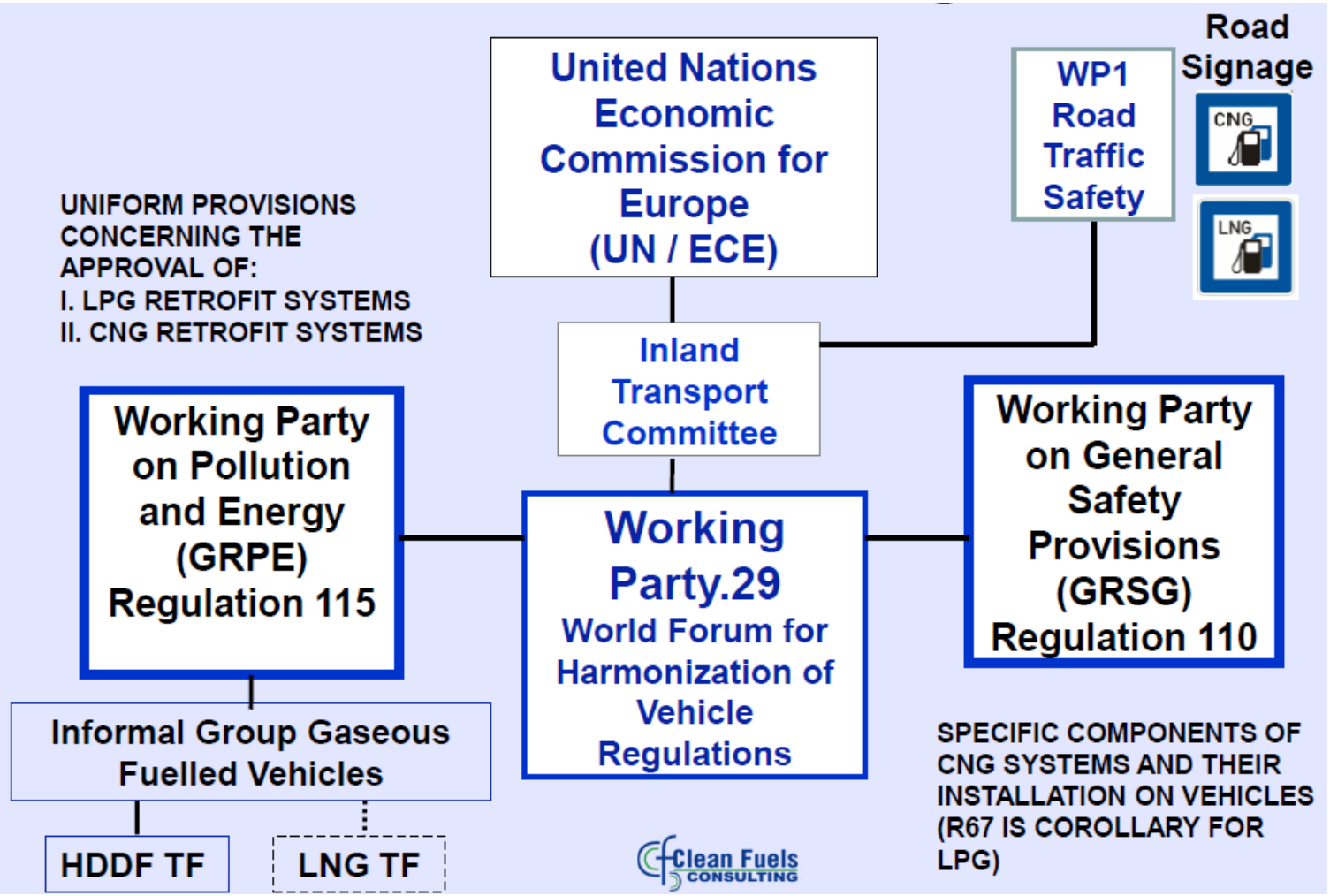
Adapted from: *Harmonization of ISO Standards and UN Regulations: New on-board components for CNG, H2 and CNG-H2 blends,* A. Bassi, SINTESI , March 2008.

ISO Standards Structure for Fuel Storage: Cryogenics & CNG



Adapted from: *Harmonization of ISO Standards and UN Regulations: New on-board components for CNG, H2 and CNG-H2 blends , A.Bassi, SINTESI, March 2008*

UN Structure for NGV Regulations

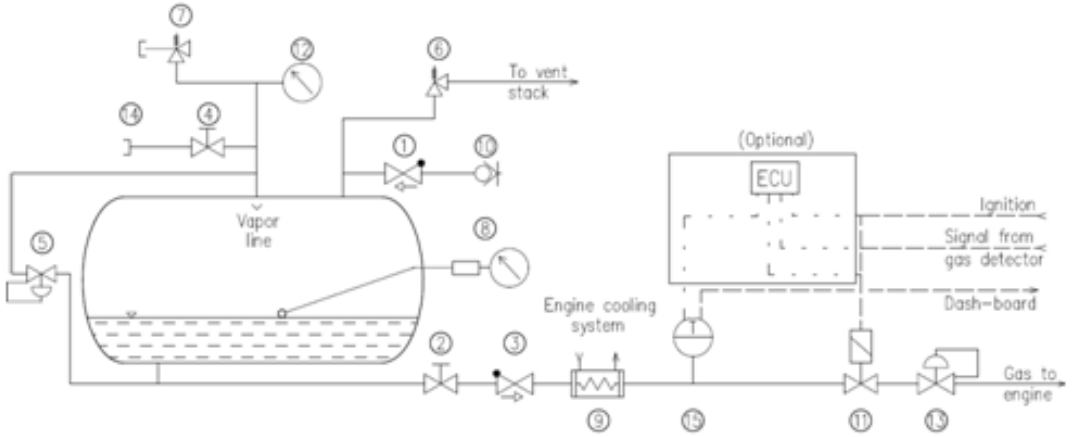


Example of basic LNG system

Annex A
(informative)

Construction and assembly

Figure A.1 — LNG fuelling system



1 Fill check valve
2 Fuel shutoff valve
3 Excess flow valve
4 Vapor shutoff valve
5 Pressure control regulator
6 Primary relief valve (PRV)
7 Secondary relief valve (PRV)
8 Fuel contents gauge
9 Heat exchanger – vaporizer
10 Fill fitting
11 Automatic fuel shutoff valve
12 Tank pressure gauge
13 Overpressure regulator
14 Vent connector
15 Gas temperature sensor
ECU Electronic control unit of engine

source ISO12614-1

Components used in the LNG part:

- ECU for CNG/LNG applications
  - Connected to the vehicles ECU
- LNG heat exchanger vaporizer
  - LNG is vaporized into gaseous state (considered CNG)
- LNG pressure control regulator
- LNG pressure / temperature sensor
- Natural gas detector
- the automatic valve, check valve, pressure relief valve, excess flow valve, manual valve and non-return valve for LNG applications

LNG components

- **LNG tank**
  - **Double insulated stainless steel tank (inner vessel, insulation and vacuumed, outer vessel)**
  - **Temperature inside -163°C**
  - **Pressure inside the tank is depending on system (between atmospheric and 1.8MPa currently)**
  - **Automatic valve**
  - **Pressure relief valve's (primary and secondary)**
    - Primary is used for venting
    - Secondary is used in case of emergency

Example of LNG tank

What is boil-off?

- A cryogenic fluid is typically kept at low temperatures in a storage vessel. The storage has a major challenge due to the inherent heat input from the environment.
- The effect of the heat input is warming of the cryogenic fluid:
  - If (constant volume) → Pressure increase in the storage vessel
  - If (constant pressure) → Fluid boils and “boil-off” vapours are released from the vessel (venting)
- *The vapours created due to the ambient heat input (while maintaining constant pressure in the storage vessel) are called “boil-off”.*
  - *The discharge of these vapours out of the storage container is called venting.*

LNG Task Force Summary
Boil Off: LNG Tanks

- Boil-off for the vehicle LNG Tank
  - LNG is a cryogenic liquid stored in a tank on-board the vehicle. Inherently heat from ambient flows in and warms the liquid.
  - For this application, the tanks are designed to take higher pressure, therefore being able to contain the LNG without release of vapour.
  - The time the tank can hold the LNG without venting is called “holding time”. By regulation 110 and codes in US and Canada the holding time is 5 days.

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International Association for Natural Gas Vehicles

LNG Task Force Summary
Conclusions: Boil Off

- The use of LNG has the inherent time factor, due to the heat input from the ambient to the vehicle tank.
- As required by codes in US and Canada, the LNG vehicle tanks are designed to contain the LNG for at least 5 days without venting.
- For normal operation, there is no release of natural gas to atmosphere.
- To avoid a dangerous condition, due to pressure increase above the maximum operating limit, the LNG tank will vent to atmosphere a limited amount of gas.

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Though designed to be ‘vent free’ it is not possible to prevent small amounts of methane escaping to atmosphere

- Commercial trucking systems are designed to match fuel consumption with fuel storage and delivery quantities
- Few commercial operators have trucks immobile for five days
- Venting in enclosed spaces (i.e. workshops) is taken into account (as with CNG) to provide proper ventilation

LNG venting management systems and techniques are well known

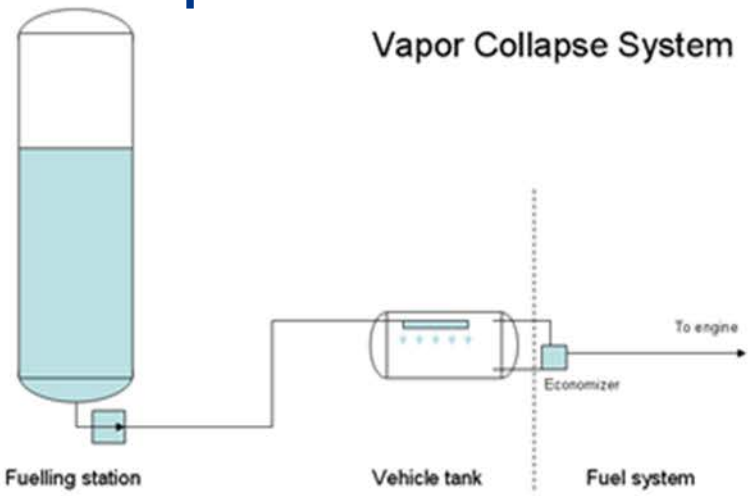
- Pressure regulator (‘economizer’ regulator) vents at pre-set pressure, opening for ~10-30 seconds and closes
- Adding LNG to the fuel tank condenses ‘warmer’ fuel
- Starting the engine or driving briefly relieves pressure in the tank and prevents venting
- Vapor recovery systems on the vehicle can be installed, sending ‘warm’ fuel back to fuelling station tanks

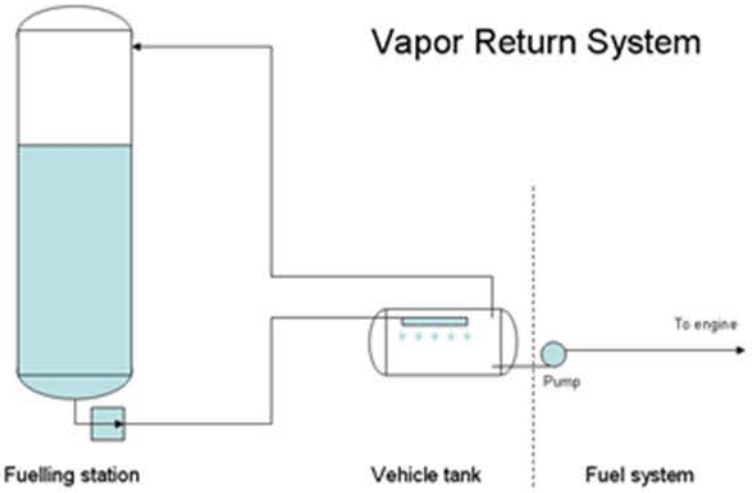
Provisions for hold time test

- **In the Regulation 110 we did insert the following test:**
  - Annex 3B 2.7. Vehicle LNG tank(s) 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.

2 Examples of heat management and types of fuel delivery systems

- Dealing with the amount of heat accumulated in the tank depends on the fuelling station and vehicle application
- Vapour transfer to fuelling station or on-board processing of vapours reduces the tank pressure and resets the clock on holding time.
- Best practice and experience is the key to successful operation.

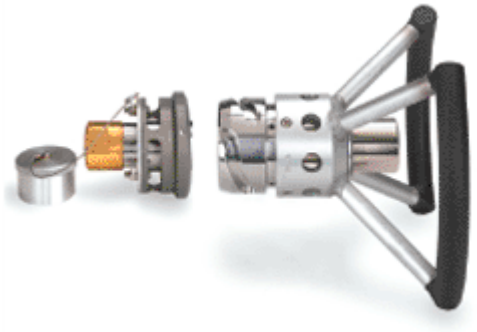




Source: Prepared for: LNG Task Force meeting in Brussels, November 3, 2011
Prepared by: Mihai Ursan, PhD., P.Eng.
Document number **TF-LNG-02-06** (Westport, paper) What is Boil-off?

LNG filling receptacle

- Spill during filling is no more than 30cm3. The filling nozzle and receptacle are a closed system.
- During filling there is no vapor. (With diesel vapor will come out of the tank during filling of the open system).
- There is a check valve (non return valve) in the receptacle.



4.76. "LNG filling receptacle" means device connected to a vehicle or storage system which receives the LNG fuelling nozzle and permits safe transfer of fuel. The receptacle consists as minimum from a receptacle body and from a check valve mounted inside the body.
18.12.1 A system shall be provided for preventing the fuel tank from being overfilled.

Automatic valve

- The content of the tank is protected with an automatic valve that in case of leakage or crash will be closed to prevent the tank from being emptied to atmosphere.
- Following provisions are in the R110 for the automatic valve:
  - “18.6.1. Automatic valve
  - 18.6.1.1. An automatic valve shall be installed in the fuel supply line, directly on every LNG tank (in a protected position).
  - 18.6.1.2. The automatic valve shall be operated such that the fuel supply is cut off when the engine is switched off, irrespective of the position of the ignition switch, and shall remain closed while the engine is not running. A delay of 2 seconds is permitted for diagnostic."

Pressure relief valve and venting system

- Primary pressure relief valve is used for venting
- Provisions in the R110 for venting:
  - 18.6.6. Vent line or connector The vent line or connector may be mounted inside or on the LNG tank (in a protected position). It should be readily accessible. The vent connector shall be suitable for the purpose at temperatures indicated in Annex 5O for the working pressure of the LNG tank.

Pressure relief valve and venting system

18.6.7. Venting management system The primary pressure relief valve shall be piped to a vent stack which extends to a high level. The primary and secondary relief valve outlets shall be protected **by from** fouling by dirt, debris, snow, ice and/or water. The vent stack shall be sized to prevent flow restriction due to pressure drop. Gas exiting the vent stack or secondary relieve valve shall not impinge on enclosed areas, other vehicles, **exterior-mounted systems with air intake (i.e. air-conditioning systems),** engine intakes, or engine exhaust. In the case of dual tanks, the primary relief valve outlets piping for each tank may be manifold to a common stack.

Vent-line

Secondary relief valve

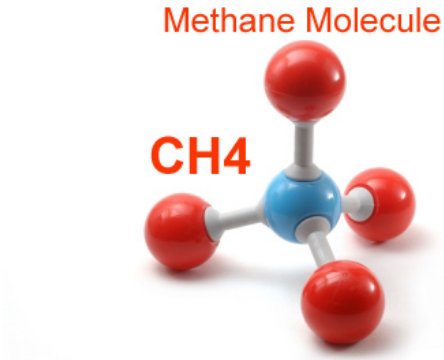
- The secondary relief valve is a redundancy of the primary relief valve
- The set pressure of the secondary relief valve is higher than the primary relief valve
- In case of an emergency the primary will operate as intend. Only in case that the primary relief valve is not working properly or can not handle the pressure build up enough the secondary relief valve is activated.

Gas tight housing and natural gas detector

- **18.13. The LNG system in category M vehicles shall be equipped with a natural gas detector and/or gas tight housing. The LNG system in category N vehicles may be equipped with a natural gas detector if the fuel storage tank and associated piping is mounted on the exterior of the vehicle without the possibility of gas trapping (as in paragraph 18.12.). If the fuel storage tank is located inside the cargo area of a category N vehicle then a natural gas detector and/or gas tight housing is mandatory.**
- **Vehicles of the N and M classes are medium and heavy duty trucks**

Comparison between LNG and Diesel

- Methane can auto-ignite at 540°C if the methane content is within the flammability range.
- Methane is lighter than air at temperatures above -110°C. Small spillages of liquid methane quickly vaporize to atmosphere. Larger spillages of liquid methane remain on the ground and vaporize. The vaporization intensity depends on the substrate, the temperature and the area covered by the spillage. The substrate eventually cools, reducing the evaporation.
- *Diesel puddles on the ground and does not vaporize quickly.*
- Diesel can auto-ignite at *210 °C*



Crash accidents

The following images are from an accident in Australia involving an LNG-fueled truck which rolled over, severely damaging the vehicle cab. As can be seen in the pictures, the LNG fuel tanks, which are mounted on a gantry at the back of the cab, were not penetrated and suffered only external damage.

Source: Chart, Inc.

Crash accidents

The images below are from an LNG-truck in California with side-mounted fuel tanks. The truck rolled onto its side, causing significant damage to the truck. The LNG tanks were undamaged in the incident.

Source:Westport Innovations

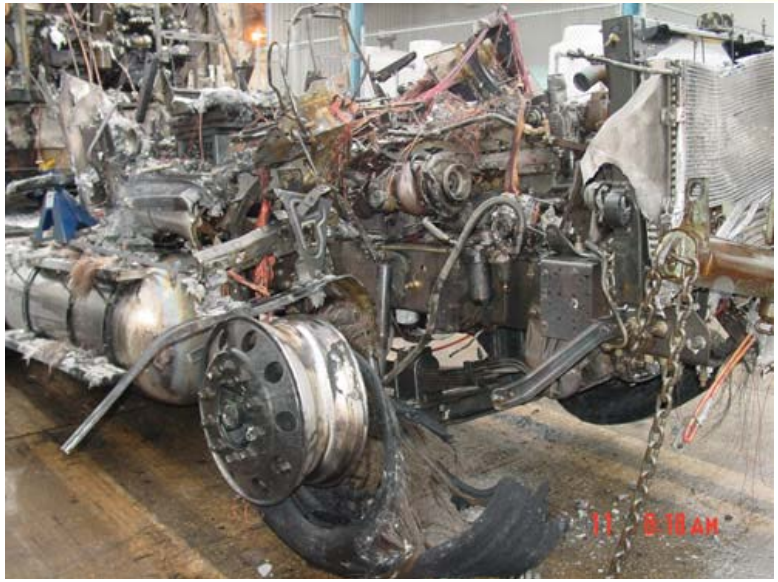
Fire accidents

In 2008, a Polish LNG bus on a test ride caught fire due to the cracking of a hose carrying hydraulic oil which ignited in the engine space. The fire spread to the inside of the bus which burned out completely.
The engine and neighboring LNG tanks were in the hottest part of the fire where temperatures were hot enough to melt aluminum materials. The LNG tank and safeguards functioned as designed, releasing its methane through the primary and secondary pressure relief devices which ejected the gas in a safe direction. The gas combusted but did not add to the burning of the bus itself and the tanks depressurized without any explosive activity.

Source: Solbus Poland

Fire accidents

- Figure 1.



- Figure 1: This thermal melt down was attributed to cab wiring. An electrical short started the fire which was not put out immediately. The result was a destroyed cab. Note that the fire raged above and forward of the LNG tank. All photos were taken the day after the fire.

Source: Clean air power

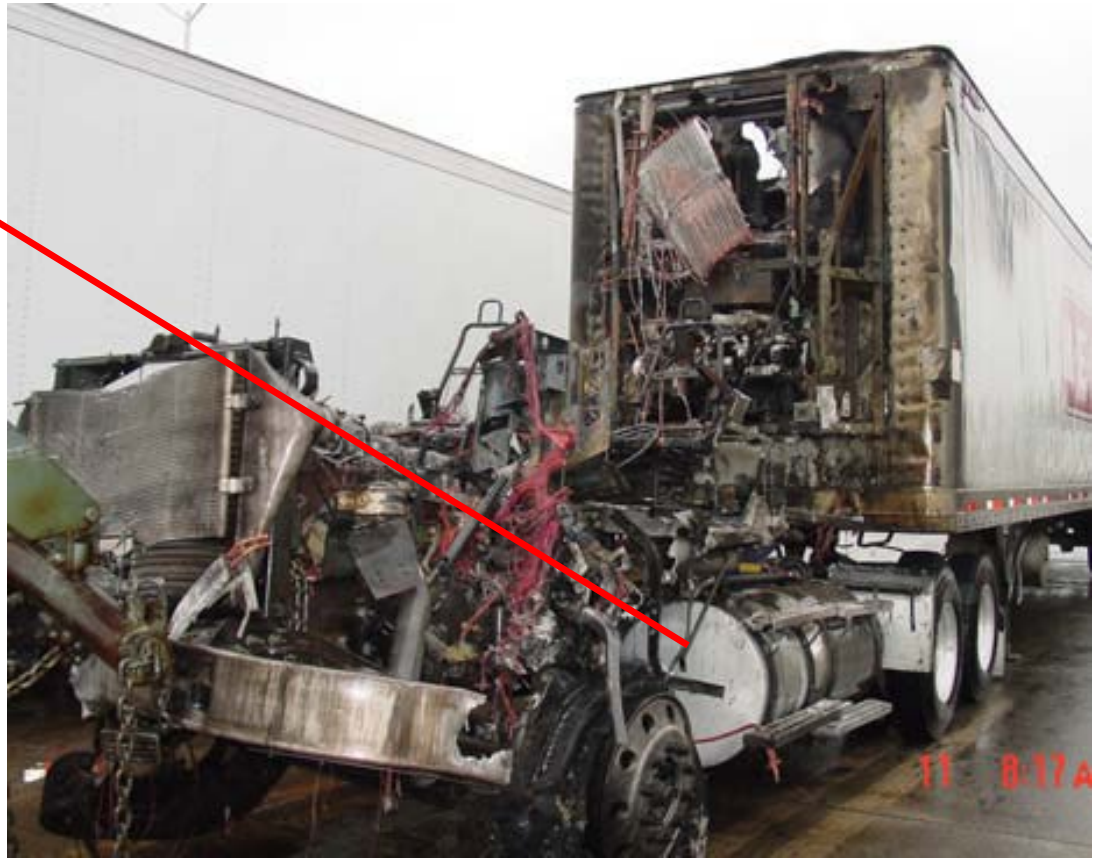
Fire accidents

Figure 2: The LNG tank's contents were not affected by the fire's heat. The vacuum insulation that keeps the ambient temperature from reaching the inner tank also kept the much higher fire temperatures from reaching the inner tank.
The door to the LNG tank was closed during the fire; note the melted plastic tube and harness covering and the pressure gauge.
The tank pressure stayed below 0.89MPa.

Source: Clean air power

Fire accidents

Figure 3: Complete melt down from other side. LNG tank



Source: Clean air power

Fire instructions

- Fire instuctions should be provided to fire-brigades.
- As example for this document the “Procedures for emergencies arising during the transportation of liquid methane (LNG and LBG) Tankers and tank containers can be used. (produced by Swedisch Gas Association – interbranch organisation for operators in the biogas, vehicle gas, LPG, natural gas and hydrogen sectors.

- Example of paragraph is like following:

Fire instructions

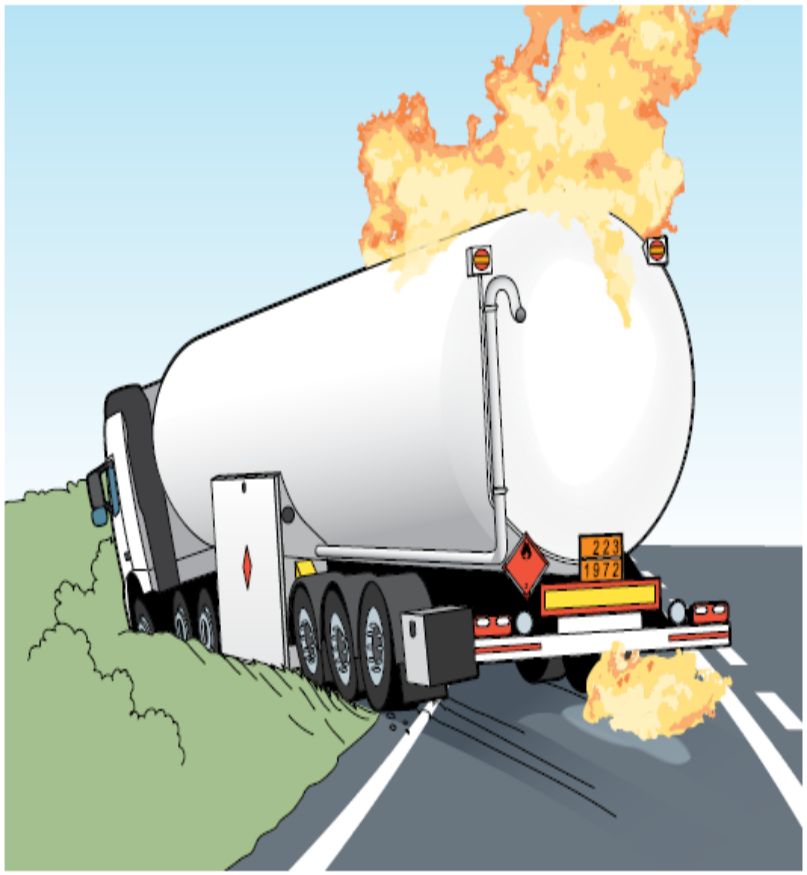
- **5.4 Transport unit leaking with fire (Scenario:)**
- The transport unit is leaking liquid and/or gaseous methane which is burning.
- **Action:**
- — Seal off an area with a radius of at least 300 m around the transport unit. The distance can be modified following consultation between the incident commander and the supplier.
- — Stop all engines and remove all ignition sources except for the transport unit from the sealed area.
- — Do not attempt to extinguish the fire without first cooling the part of the transport unit exposed to the radiated heat from the fire. Note: the water must not come into contact with the liquid methane. Water produces energy, which increases evaporation and may in turn increase the intensity of the fire. Note: extinguishing the leaking gases without shutting off the flow of gas creates a high risk of re-ignition. As previously mentioned, the tank construction provides a high level of passive fire protection.

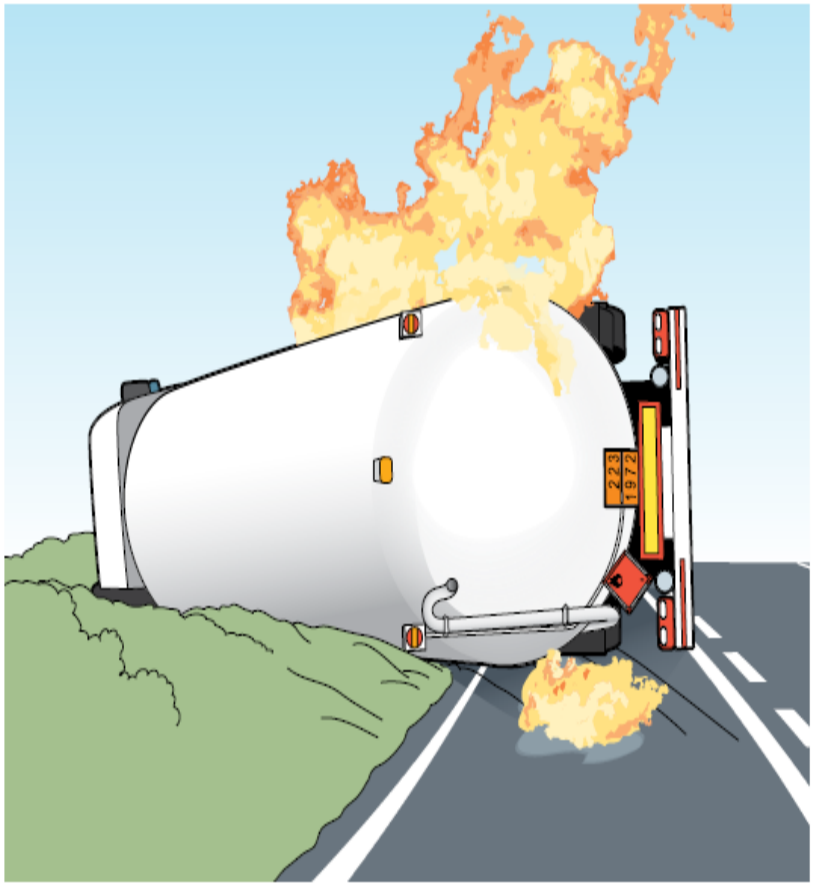
Source: Swedisch Gas Association – interbranch organisation for operators in the biogas, vehicle gas, LPG, natural gas and hydrogen sectors

5.4 Transport unit leaking with fire

Scenario:

- The transport unit is leaking liquid and/or gaseous methane which is burning.





Fire instructions

- — If possible, remove other vehicles containing hazardous cargo from the risk zone. If this is not possible, these vehicles should also be cooled using water.
- — Determine whether the leak can be stopped by shutting off the gas/liquid supply.
- — If it is possible to extinguish the fire in order to allow the gas supply to be shut off, powder should be used as an extinguishing agent.
- — If the fire cannot be extinguished, allow the gas to burn while the tank is cooled, until the tank is empty or the fire goes out.
- — If the transport unit needs to be emptied, the procedure must be determined jointly by the incident commander and the supplier.
- — The supplier must authorize removal of the transport unit.

Design requirements on the LNG system

- **The LNG/CNG tank(s) cylinders shall be at least 200 mm of the flour level (for diesel there are no shuch definitions)**
- **The mounting of the tanks shall comply with the G-forces mentioned in the regulation:**
  - 18.4.4. The fuel container(s) and/or tank(s) shall be mounted and fixed so that the following accelerations can be absorbed (without damage occurring) when the container(s) and/or tank(s) are full.

Tests required on LNG Tank and components

- Hold time test. (no venting allowed within 5 days)
  - The LNG tank is tested at maximum allowed net quantity of LNG.
  - Provisions are given in R110 annex 3B A.2

Tests required on LNG Tank and components

- **Drop test**
  - **2 drop tests are required**
    - 9 meter drop test of the fuel tank on the most critical area of the tank (other than the piping end).
    - 3 meter drop test on the piping end.

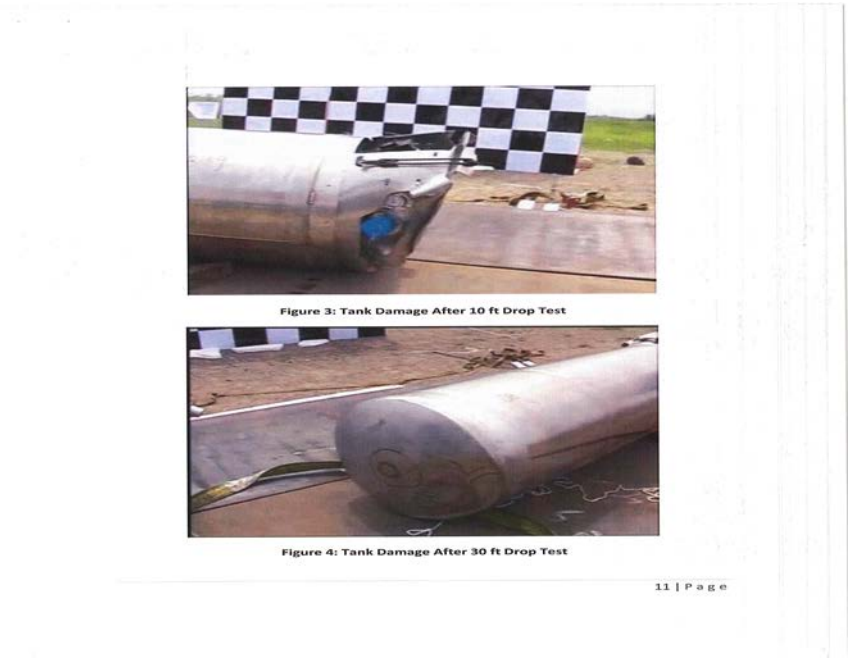


Figure 3: Tank Damage After 10 ft Drop Test

Figure 4: Tank Damage After 30 ft Drop Test

11 | Page

Source:Transport Canada

Tests required on LNG Tank and components

- **Bonfire test**
  - **The bonfire tests are designed to demonstrate that finished tanks with the fire protection system (tanks valve, pressure relief valve and/or integral thermal insulation) specified in the design will not burst when tested under the specified fire conditions.**
  - **Provisions are given in R110 annex 3B A.1**
  - **The average temperature of the fire source shall remain above 590°C.**

Tests required on LNG Tank and components

- The pressure inside the LNG tank will rise very slowly due to the insulation.
- LNG will be vented until the pressure is lowered like in normal use.
- Diesel will start to boil and the pressure in the tank will rise.
- Worst case the diesel tank will explode.

Source:picture: Chart

Tests required on LNG Tank and components

- **Material tests on the tank**
  - Tensile test
  - Impact test
  - Bending test
  - Weld examination
- **Low temperature test (-163°C).**
  - All LNG components are to be tested at -163°C for leak tightness.
  - All duration tests on LNG components should use the low test temperature (-163°).

Coming soon….clean, economical LNG for the transportation sector

Important sites:

- http://www.unece.org/trans/main/wp29/wp29regs.html
- http://eur-lex.europa.eu/en/tools/sitemap.htm
- http://www.kiwa-expertcentres.com/expertcentres/eup/yourproducts/automotive-products-components.aspx

On behalve of the LNG-TF

Thanks for your attention

Questions and Clarifications?

Informal Document
presented to
WP15 -Transport of Dangerous Goods
6 November 2013
United Nations
Geneva

LNG: A SAFE FUEL FOR TRUCKS

NGV Global

Purpose: Advocate for a change in ADR regulations that prevent LNG vehicles from being ADR-certified

- While LNG is allowed for general transport purposes it is not allowed for ADR-certified vehicles.

ADR regulations provide an exemption related to the carriage of gases so long as the gas is used for propulsion or operating on-board equipment.

Annex A: 1.1.3.2 Exemptions related to the carriage of gases

The provision laid down in ADR do not apply to the carriage of:

Gases 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 (e.g. refrigerating equipment)

But……

Annex A: Chapter 9.2. subsection 9.2.4.3 ***Fuel tanks :*** *The fuel tanks for supplying the engine of the vehicle shall meet the following requirements:*

In the event of ***any leakage, the fuel shall drain to the ground*** *without coming into contact with hot parts of the vehicle or the load;*

NGV Global

LNG Safety Characteristics

- Natural gas liquefies at -163ºC
- LNG is not flammable (due to its density). Only the vapor will ignite when the concentration is between 5% and 15% by volume in air.
- LNG is non-toxic, non-corrosive and does not contaminate soil or ground water.

- When spilled LNG, vaporizes creating a white cloud of condensed moisture.
- The vapor cloud is heavier than air until it reaches -112ºC, then it disperses quickly (like methane in its normal gaseous state).

Source: LNG Safety: Integrating Standards, Regulations, Best Practices & Compliance, Douglas Horne, Clean Vehicle Education Foundation at LNG is Hot Workshop, Clean Fuels Consulting, Brussels 2009.

Global Overview on the Development of LNG Trucks

- Summary world market for LNG & trucks
- European LNG truck development
- Development of LNG truck market: North America
- LNG truck developments: China & Australia
- Fuel suppliers' vision of LNG for trucks

NGV Global

Current Global View: HDV NGVs

REGION	TOTAL NGVs	MD/HD BUSES	MD/HD TRUCKS	% MD/HDV TRUCKS of TOTAL NGVs
ASIA	9,733,192	390,849	155,207	1.6%
EURASIA	336,862	32,200	52,760	15.7%
AFRICA	188,220	1,463	85	0.45%
EUROPE*	1,735,115 (1,347,115)	278,472 (45,684)	193,759 (57,966)	11.2% (4.3%)
S & CENTRAL AMERICA	4,608,799	13,920	9,660	0.21%
NORTH AMERICA	131,036	13,230	~15,550(1) (~4000 L-NGVs)	11.8%
WORLDWIDE	16,424,603	697,596	361,748	2.2%
*UKRAINE	388,000	232,788	135,793	35%

Source: Gas Vehicle Reports, Aug/September 2012/13, NGVAmerica
(1) US/Canada NGV Market Analysis (segmentation), Tiax/ANGA,2010

Clean Fuels CONSULTING

International Standards & Regulations are Being Developed for L-NGVs

United Nations Regulations

- **Amendments to R.110 for L-NGV components & installation (awaiting approval by WP29)**
- **Dual-fuel trucks (including LNG) R.49**
- **Fuel station signage agreed at UN (WP1)**

ISO Standards Development is on-going

- **Fueling stations and storage require harmonized global regulations, current national standards are insufficient.** ***(ISO standards underway)***
- **Tanks for on-board storage** ***(ISO 1299/2012 standard completed)***
- **Harmonized fuel connector/receptacle needed** ***(ISO standard underway)***

NGV Global

World Forecast LNG Trade Through to 2030

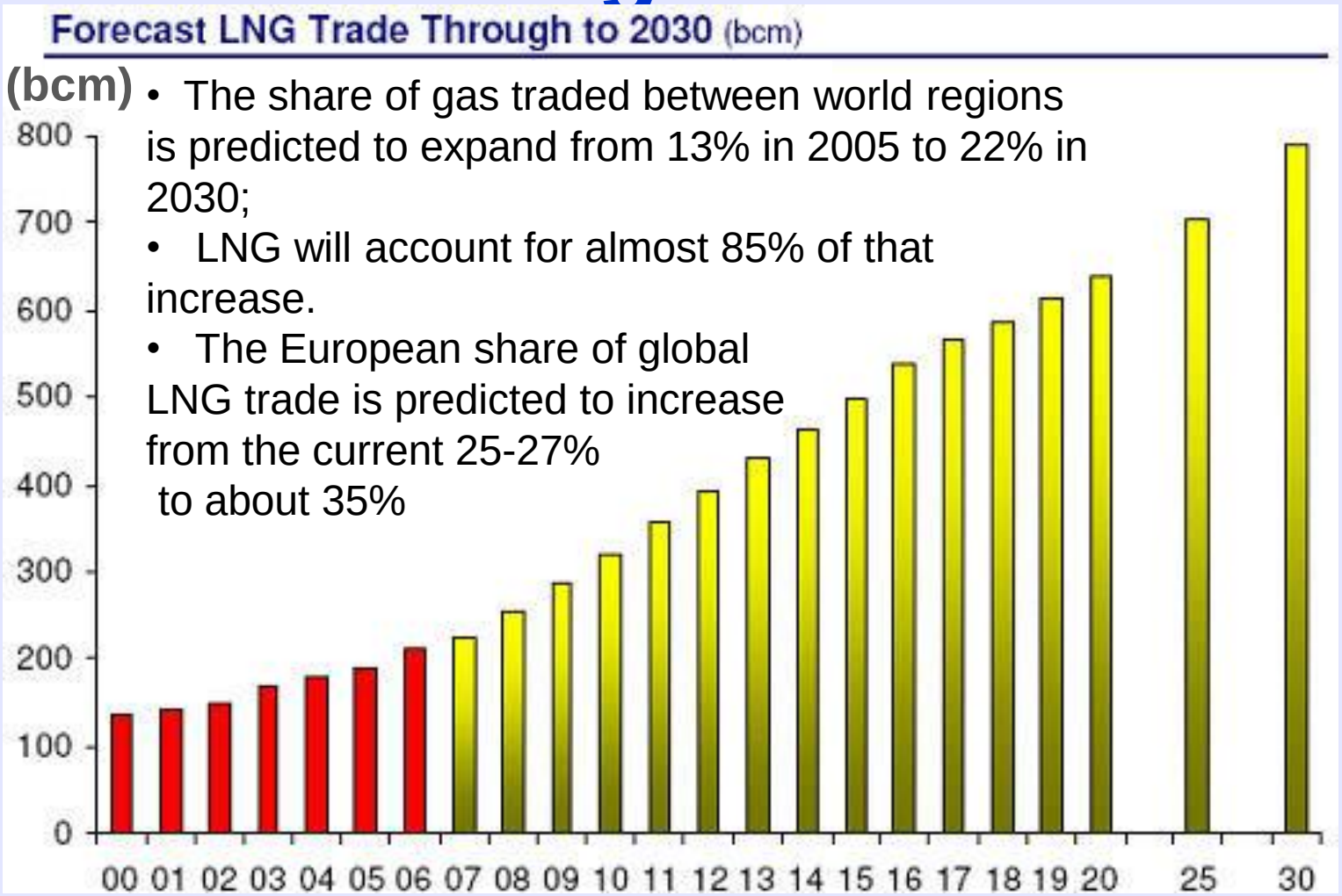
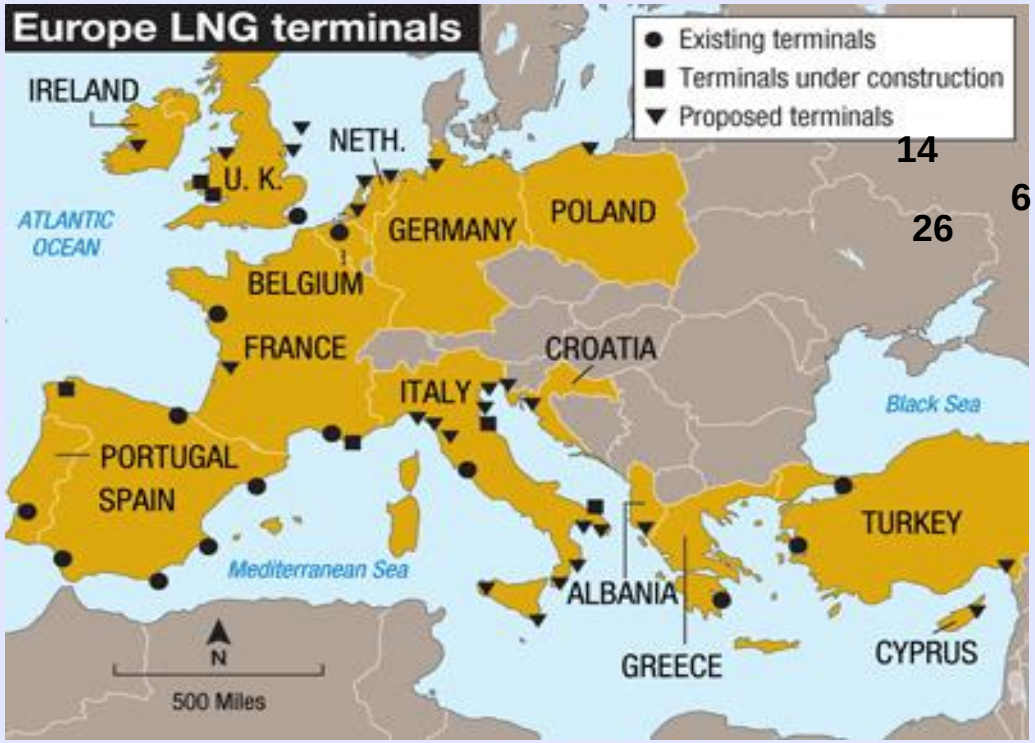


Image source & EU LNG projections: Ocean Shipping Consultants Limited (2008)

Clean Fuels CONSULTING

Expansion of LNG terminals provide new opportunities for L-NGV fuelling stations in different countries



European OEM LNG Trucks

- IVECO
  Stralis LNG
- Mercedes
  Econic LNG
- Scania
  P310 LNG
- Volvo
  FM MethanDiesel

NGV Global

European LNG Truck Fleets
Rolande

- Rolande (NL/F/D) supermarket distribution (12 Iveco Stralis trucks)
- 6 L-CNG stations NL
- Fuel costs savings over diesel = €8,600 to €15,000 per vehicle per year (over 7 years)

Source: Rolande 2012

NGV Global

Clean Fuels CONSULTING

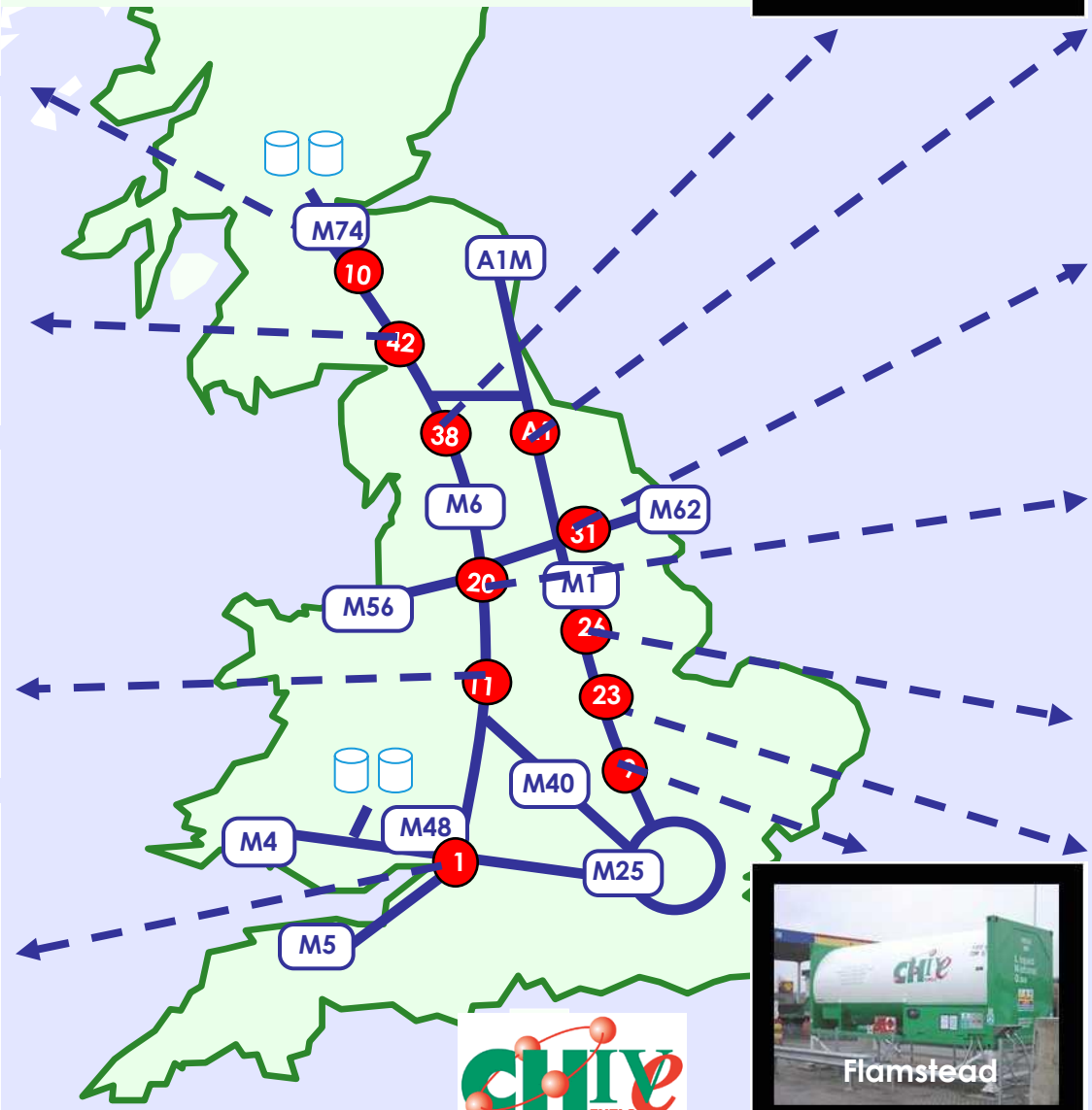
European LNG Truck Fleets
Simon Loos (NL)

- 30 Mercedes LNG trucks deployed in 2012
- Pollution reduction:
- CO_2 -30%
- Particulates -85%
- Noise -30%
- 600-700 km range
- Fuel consumption = diesel

NGV Global

Clean Fuels CONSULTING

CHive LNG REFUELLING NETWORK: Some stations are inactive due to current LNG fleet demand (2013)



Barcelona LNG Garbage Trucks

- With five terminals currently in operation, Spain is the largest LNG market in Europe. (World's third-largest LNG importer after Japan and South Korea.)
- LNG makes up around 70% of Spanish natural gas supplies.
- For over 8 years LNG has been used as a transport fuel in Barcelona.
- Barcelona's LNG garbage trucks belong to CESPA and are hired by Barcelona city council.

Chassis is made by MAN and Ros-Roca, Indox, Messer and Gas Natural have assisted the project.

LNG for Heavy Duty Vehicles
(USA)

Passenger Bus

- 150 LNG fuelling stations

(42 public)

- 4,000+ L-NGVs
  - Freightliner
  - Kenworth
  - Peterbilt
  - Autocar
  - Capacity
  - Navistar?
  - Volvo?

Refuse Truck

Street Sweeper

NGV Global

Local, Regional HD NGV Trucks

NGV Global

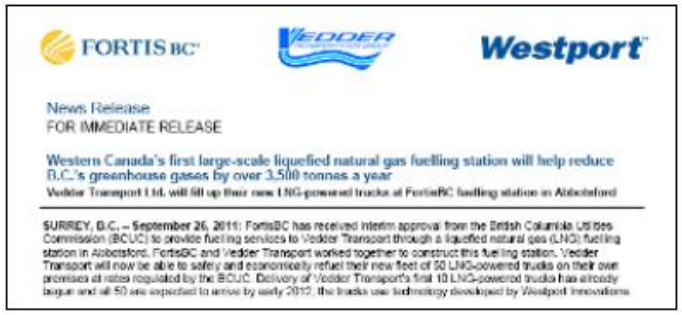
LNG truck stations Western US

41 L-NGV Stations in Southern California

GLADSTEIN, NEANDROSS & ASSOCIATES

N. American LNG Truck Case Studies
Vedder Transport

- Largest fleet in British Columbia, Canada – high environmental commitment
- 50 new LNG tractors
- Hauling milk, food, forestry and waste products in dedicated service
- 3500 tonne annual GHGe reductions from implementation
- Cost reductions result in ~16 month payback
- 1 fuelling station – public access


FORTIS BC VEDDER Westport

News Release
FOR IMMEDIATE RELEASE

Western Canada's first large-scale liquefied natural gas fuelling station will help reduce B.C.'s greenhouse gases by over 3,500 tonnes a year

Vedder Transport Ltd. will fill up their new LNG-powered trucks at FortisBC fuelling station in Abbotsford

SURREY, B.C. – September 26, 2011: FortisBC has received interim approval from the British Columbia Utilities Commission (BCUC) to provide fuelling services to Vedder Transport through a liquefied natural gas (LNG) fuelling station in Abbotsford. FortisBC and Vedder Transport worked together to construct this fuelling station. Vedder Transport will now be able to safely and economically refuel their new fleet of 50 LNG-powered trucks on their own premises at rates regulated by the BCUC. Delivery of Vedder Transport's first 10 LNG-powered trucks has already begun and all 50 are expected to arrive by early 2012. The trucks use technology developed by Westport Innovations

VEDDER TRANSPORT

N. American LNG Truck Case Studies
United Parcel Service

- Largest private fleet in USA – environment, energy security concerns
- 82 new LNG tractors – operating between Los Angeles, Las Vegas and Salt Lake City Distribution Centres
- 688 mile (1107 km) corridor with 3 fuel stations
- 4 fuelling stations
  - – public access
- ~5100 tonne annual GHGe reductions from implementation

LNG for Port Applications

(Examples in Long Beach, California, USA)

CHINA

22 LNG receiving terminals being built

350 L-NGV Fuelling Stations; 13,300 L-NGVs*

Slide adapted from GAS ADVISERS 3 Dec 2009

**Vehicle data: Westport 2013 (US DOE-EIA)*

Currently 10 Operational LNG Refueling Stations with 4 More Planned, All on Major Trucking Routes.

Evol LNG storage

- LNG production plant
- 10 Current LNG Stations
- 4 Future LNG Stations

Source: EVOL LNG May 2009

Clean Fuels CONSULTING

LNG FOR TRUCKS
The fuel suppliers' views….

Also as fleet operators of trucks & ships

NGV Global

Shell Vision LNG Vehicles
Road & Marine Transport

NGV Summit, FC Business Intelligence, Brussels October 2012

Shell Vision for LNG Trucks in N. America: $100m investment in LNG & L-CNG fuelling stations

GREEN CORRIDOR - CANADA

- Canadian Green Corridor, 1500 km Vancouver – Calgary - Edmonton
- Shell Flying J Network
- Sites opening end 2012

Shell Vision… Europe

- Focus on Marine & Road
- North West Europe
- Including Addressing Own Demand
  - 2 barges with ISB on Rhine

"Shell owns 1,800+ vessels & target 25% to be using LNG by 2025." (Poli-techs, March 2013, Brussels)

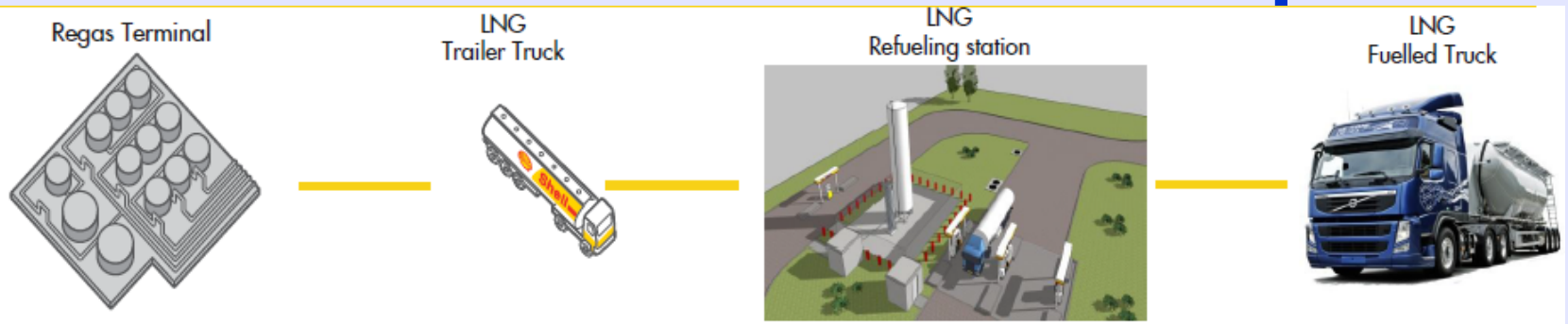
GATE

GASNOR

ROAD

INLAND WATERWAYS

Shell view of LNG for Transport



CRITICAL SUCCESS FACTORS

Conversion Cost

- LNG refueling station will be 3-5 times more expensive then current diesel station
- Increased availability of LNG fuelled trucks at a lower cost
- Cost reduction across the supply chain

PRICING

- Governed to lower your total costs of ownership
- Enabling to provide customers a high quality fuel at discounted diesel prices

REFUELING NETWORK

- Network Plan for LNG sites on existing Truck network
- Align with customer priorities

Linde is a leader supplier of LNG and LNG fuel stations

Linde North America has purchased 23 LNG trucks for own distribution fleet

THE LINDE GROUP

- **Peterbilt and Kenworth LNG trucks** with LNG fuel system and 8.9L NG engine
  - Cummins West Port ISLG Engine
  - 350 HP
- Trucks deployed in **Southern California, Texas and Midwest**
- Lower weight, spark ignited units has even **improved pay-load**

Take-out: Good driver experience and economics in line with expectations. Linde always operating weight restricted which is limiting areas were low horse power engines can be used.

Linde view of what's required for LNG to penetrate the heavy truck market

- Codes & standards need to come in place, beyond local ones
- Industry must put „Safety first"
- Gas quality requirements needs to be sorted out (not that easy)
- Never accept solutions allowing methane to free air to be adopted
- Hen & egg situation can be solved
- LNG and CNG goes hand-in-hand and LNG is not a viable option for every heavy vehicle!
- Biomethane likely to play significant role on many markets as transport fuel and EU wide regulations on certificate trading needed
- All stakeholders need to work close together to align expectations and set priorities during early market phase

Informal Document
presented to
WP15 -Transport of Dangerous Goods
6 November 2013
United Nations
Geneva

LNG: A SAFE FUEL FOR TRUCKS

NGV Global