

# ***CNG for Heavy Duty***

Clean Cities Transportation

March 30-31, 2011

**Workshop for Almaty**

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# ***Agenda***

- ***Heavy-Duty vehicle for CNG***
- ***Mono-Fuel Technology***
- ***Dual-Fuel Technology***
- ***Challenges to introduce CNG Technology***
- ***Safety on CNG Vehicles***
- ***Standards & Regulations***
- ***Conclusions & Recommendations***

# Heavy Duty CNG Vehicles

## ➤ **On-Road**

- ✓ **Trucks**
- ✓ **Busses**



## ➤ **Off-Road**

- ✓ **Agricultural / Community Tractors**
- ✓ **Forestry Equipment**
- ✓ **Construction Machines**
- ✓ **Terminal Tractors**
- ✓ **Material Handling (forklifts)**



source : Kalmar

# Gas Engines Heavy-Duty Vehicles

## ➤ **Mono-Fuel**

### ✓ **OEM available**

- **Natural Gas (CNG / LNG)**
- **Biomethane (CBG / LBG)**

## ➤ **Dual-Fuel**

### ✓ **OEM**

- **Available by some manufacturers**

### ✓ **A-OEM**

- **Available in some countries**

### ✓ **Retrofit**

- **Several available**



source : MAN engines



source : Clean Air Power



# ***Monofuel Heavy-Duty Vehicles***

## **➤ *Advantages***

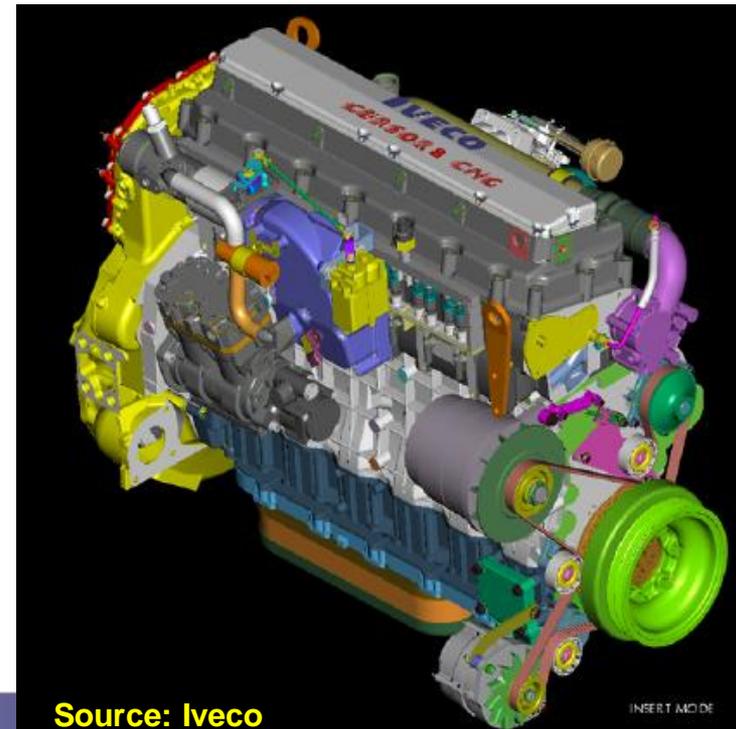
- ✓ ***Dedicated engine → optimal use of Methane as fuel***
- ✓ ***Maximum amount of CNG cylinders → max. range***
- ✓ ***Secured use of CNG***
  - ***No theft of fuel***
  - ***Optimized emissions***

## **➤ *Disadvantages***

- ✓ ***Restricted to infrastructure***
  - ***Restricted range***
  - ***No alternative if infrastructure fails***
- ✓ ***High development costs for engine***

# ***How does Mono-Fuel work?***

- ***Use of Otto principle*** (Spark Ignition)
  - ✓ ***Engine dedicated for CNG***
  - ✓ ***Engine equipped with ignition system***
  - ✓ ***Engine equipped with catalytic convertor***
  
- ***Low emissions compared to Diesel***
  - ✓ ***In particular NOx and Particulates***

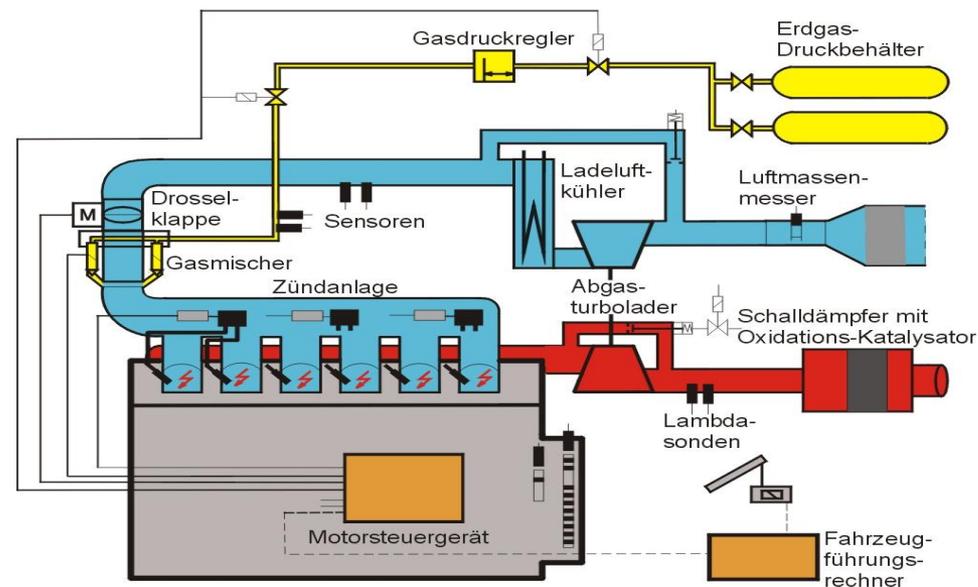


Source: Iveco

INSERT: IAC/DE

# ***Mono-Fuel engine for Heavy-Duty***

- ***Complete new Engine development***
  - ✓ ***High development costs***
  - ✓ ***High homologation costs***
- ***Mainly interesting for OEM application***



source : MAN



# ***Dual-Fuel Heavy-Duty Technology***

## **➤ *Advantages***

- ✓ ***No restrictions of CNG infrastructure***
  - ***100% Diesel operation as backup***
  - ***Extra long range → CNG + Diesel***
- ✓ ***Relative low development costs for engine***

## **➤ *Disadvantages***

- ✓ ***Compromise on technology Diesel / Gas***
- ✓ ***Potentially worse emissions than original Diesel engine***
- ✓ ***Limited use of CNG as fuel***

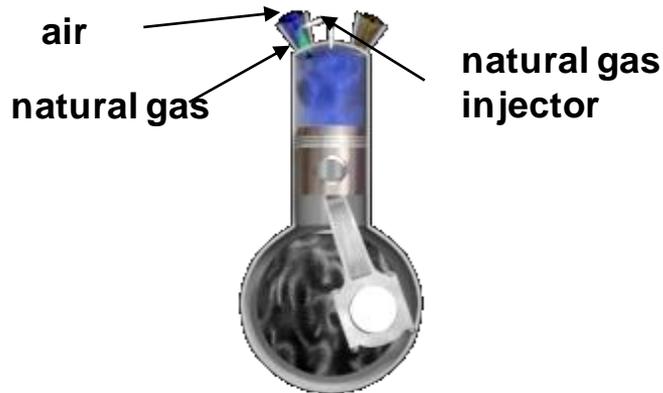


## ***How does Dual-Fuel work?***

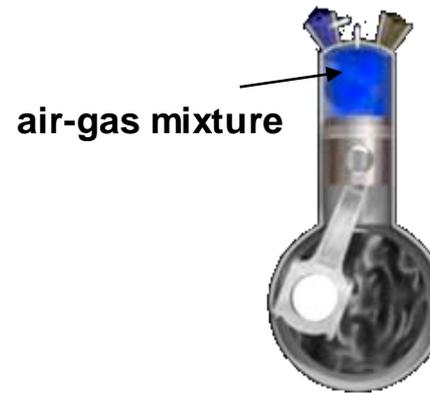
- ***Use of Diesel engine*** (Combustion Ignition)
  - ✓ ***Only limited modification to base engine necessary***
- ***Certain amount of Diesel is replaced by gas***
  - ✓ ***Theory : replacement up till 98%***
  - ✓ ***Praxis : circa 70 – 80 % average***
- ***Gas/air mixture ignited by Diesel injection***
  - ✓ ***Gas/air mixture during intake stroke***
  - ✓ ***Westport → HPDI technology***
- ***Electronic Control unit required***
  - ✓ ***Inject correct amount of Gas and Diesel***

# Typical Dual-Fuel Technology

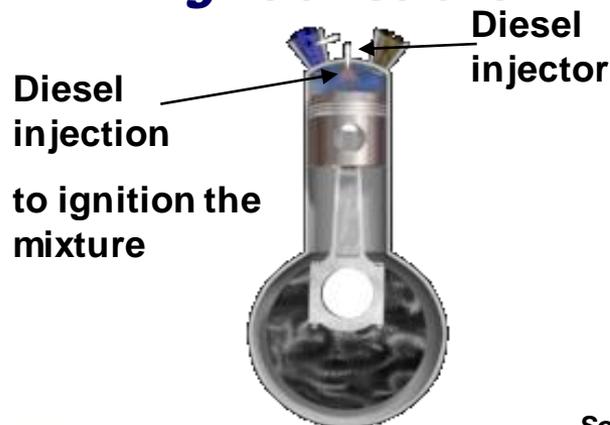
***inlet stroke***



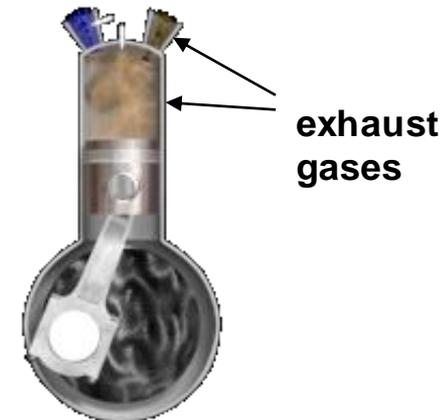
***compression stroke***



***ignition stroke***



***exhaust stroke***

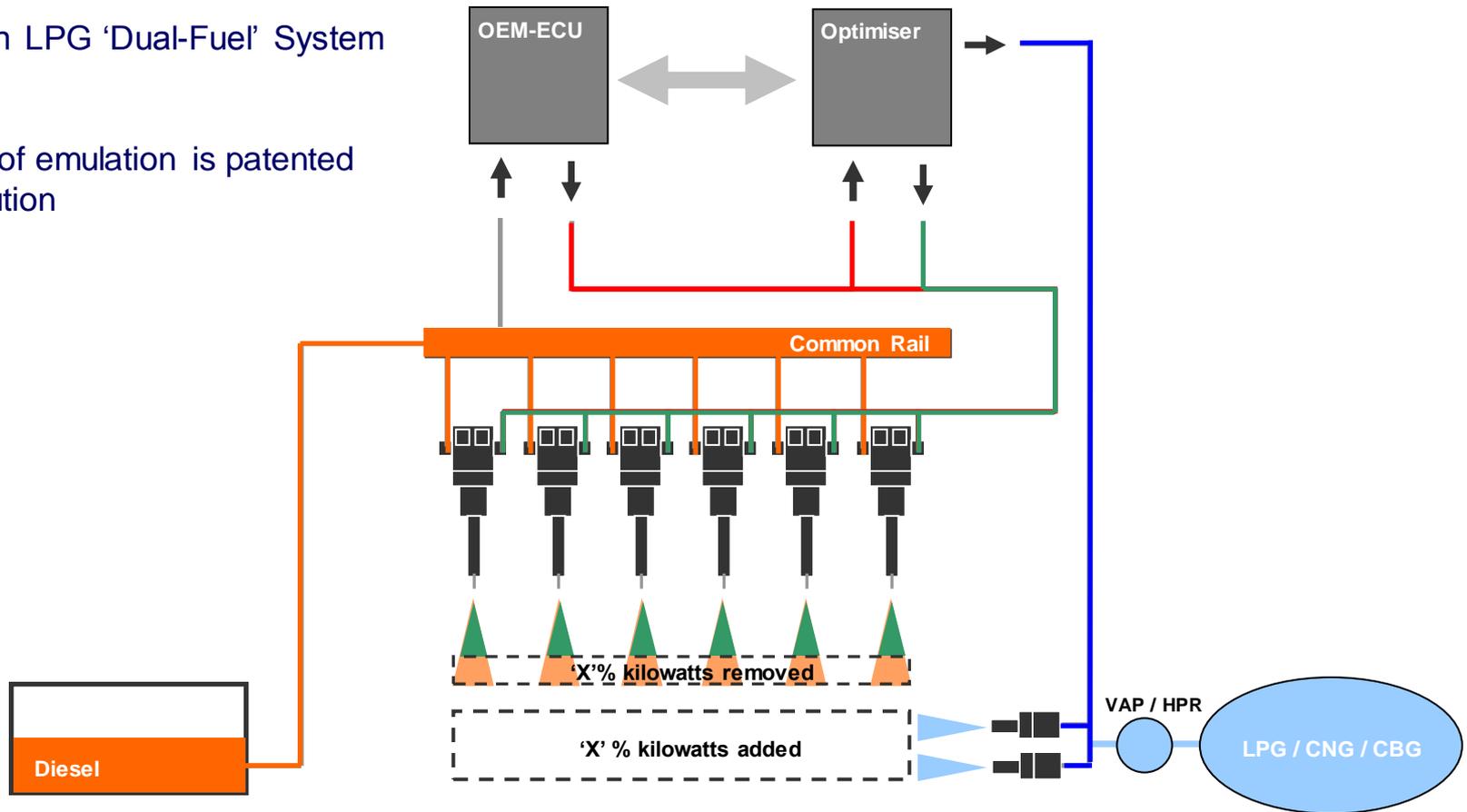


Source : CAP (Clean Air Power)

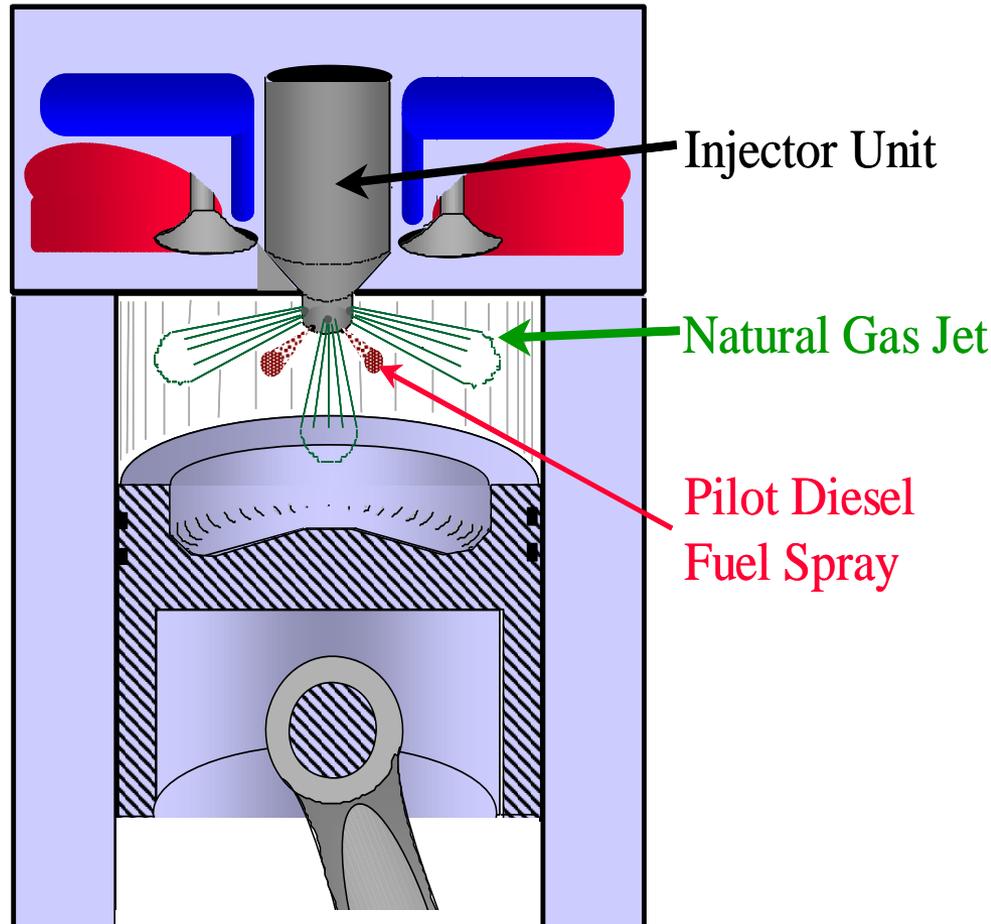
# Dual-Fuel technology

G-Volution LPG 'Dual-Fuel' System

Principle of emulation is patented by G-Volution



# Westport Dual-Fuel technology



Source : Westport Innovations Inc.

Cummins Westport

Dual-fuel engine with one (1) combined CNG / Diesel injector



Diesel  
Injector

HPDI  
Injector

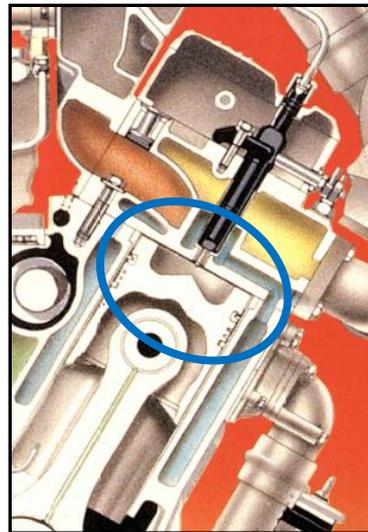
Source : Westport Innovations Inc.

# ***Technical Challenges Dual-Fuel***

## ➤ ***Emissions***

- ✓ ***Hydrocarbons***
- ✓ ***NO<sub>x</sub>***

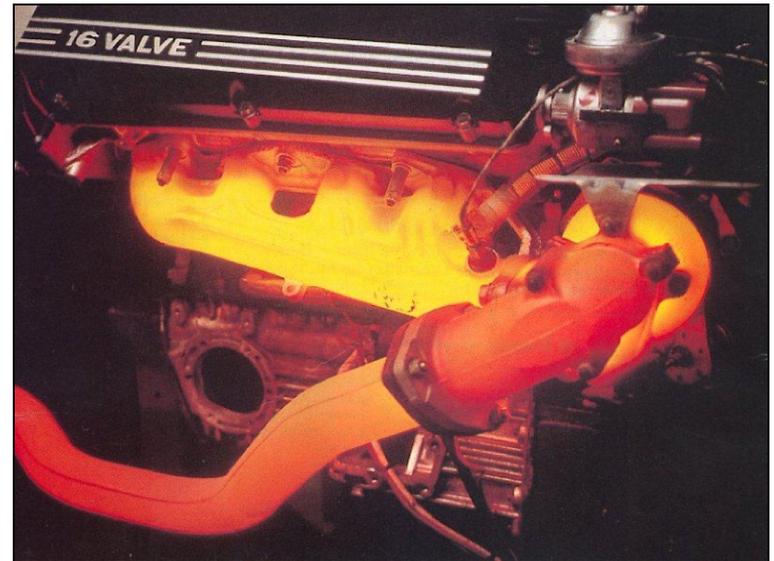
***Technical solutions will come if regulation is available***  
*(emission limits)*



# ***Technical Challenges Dual-Fuel***

## ➤ ***Engine Durability***

- ✓ ***Temperatures***
- ✓ ***Combustion peak pressure***
- ✓ ***Prevent for Pre-Ignition***



# ***Technical Challenges Heavy-Duty vehicles***

## ➤ ***Gas Storage***

- ✓ ***Heavy-Duty vehicles often have dedicated design***
- ✓ ***Typically not much room for gas bottles***
- ✓ ***Use under rough conditions***
  - ***Extreme temperatures***
  - ***Subject to high vibration / shock***
  - ***Dirt, Dust, Chemicals, etcetera***



Photo: Courtesy of Patrick L. Bishop



# Operation Challenges

## ➤ Refueling

- ✓ **Create sufficient On-Board gas storage**
- ✓ **Overnight refueling** or
- ✓ **Refueling on location**
- ✓ **LNG to increase range**

## ➤ Service

- ✓ **Training service network on gas system**

## ➤ **Regulation** of Off-Road Dual-Fuel Equipment

- ✓ **Components**
- ✓ **System Lay-Out**
- ✓ **Emissions**



Source : RAVO



Source : xperion



# ***Existing Regulations for CNG / LNG***

## **➤ Components**

**✓ CNG & CBG : UN ECE R110 → apply to Motor Vehicles**

## **➤ System Layout**

**✓ R110 applies on Class N and M vehicles**

**✓ UN ECE R115 applies on Class N and M vehicles**

***Regulation is required for OEM, A-OEM and Retrofit Dual-Fuel programs***



# ***Emission Regulation Europe***

## **➤ Emissions**

- ✓ **Pass. Cars & LCV** ( $N_1 / M_1$ ) : **Euro 1, 2, 3, 4, 5, 6**
- ✓ **Trucks & Buses** ( $N_{2/3} / M_{2/3}$ ) : **Euro I, II, III, IV, V, VI, (EEV)**
  - **Petrolengines**
  - **Dieselengines**
  - **Gasengines** → **Monofuel or Bi-fuel**
  - **Dual-Fuel Gasengines** → **No regulations available yet**

***Regulation for Dual-Fuel is needed, but worked on.***

# Commercial Chances

- Request for **Clean and Energy Efficient Technology** from :
  - ✓ (local) governments
  - ✓ environmental friendly operating companies
- Possible to fill in a “niche market”
- Cost saving possible (depending on fuel prices)
- Industry sometimes is conservative



Handling equipment  
LPG / CNG is “well known”



Agricultural- / Forestry- / Building equipment, etcetera  
Gas is NOT very well known



# ***Commercial Chances CNG***

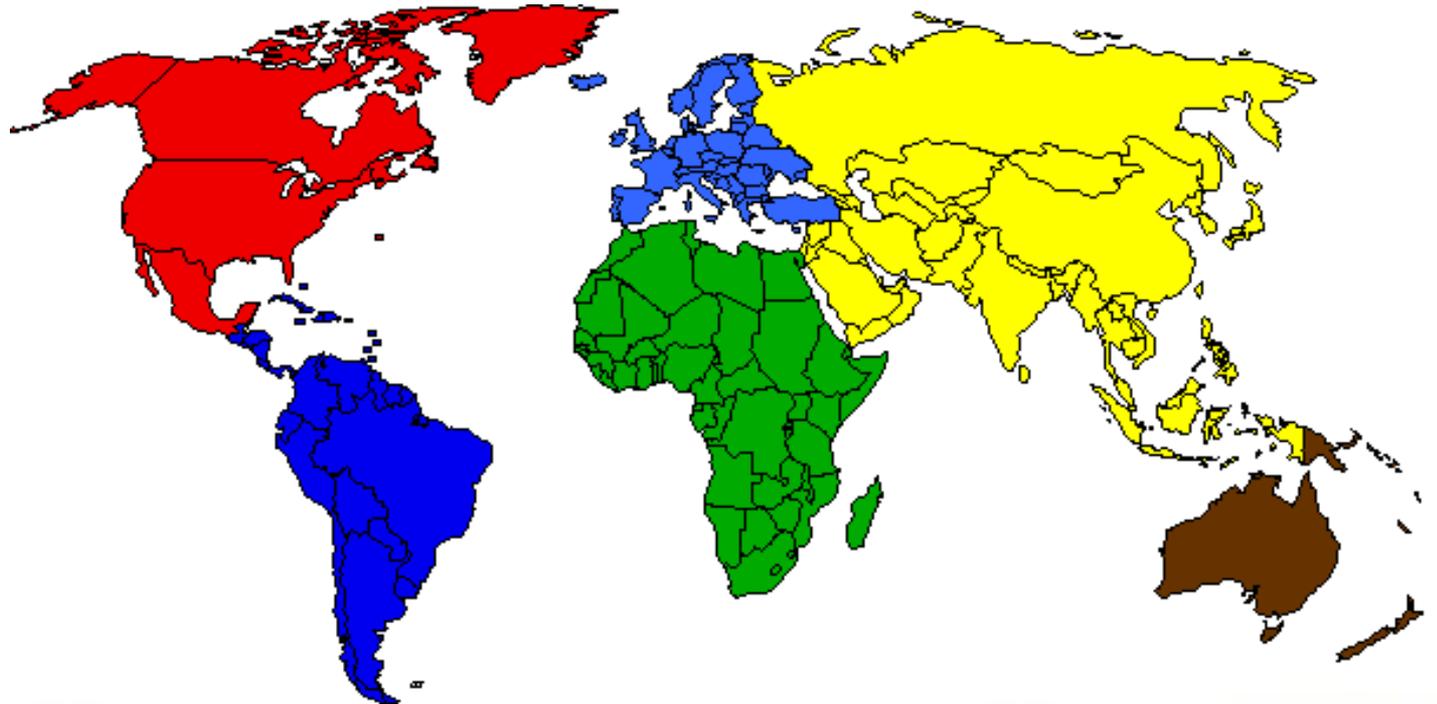
## ➤ ***Especially for local operated fleets***

- ✓ ***Busses***
- ✓ ***Garbage trucks***
- ✓ ***Local / Regional Parcel delivery***
- ✓ ***Terminal tractors***
- ✓ ***In-building operations***
- ✓ ***Etcetera***



# ***Regional differences***

- ***Huge regional differences in***
  - ✓ ***Quality awareness***
  - ✓ ***Safety awareness***
  - ✓ ***Required System- & Component prices***





## ***Quality of CNG system***

- ***Implement regulations for component approval***
  - ✓ ***UN ECE R110***
- ***Implement regulations for system approval***
  - ✓ ***UN ECE R110 for OEM***
  - ✓ ***Based on UN ECE R115 for retrofit***
  - ✓ ***Vehicle Inspection for retrofit systems***



## ***Safety of CNG system***

- ***Use only approved components***
- ***Introduce training and certification***

# ***Real Accidents -- CNG is Safe !!***



**USA, 2004**

**OEM Honda CNG hit in the back.**

- ✓ No leakage
- ✓ No fire
- ✓ No explosion

# ***Real Accidents -- CNG is Safe !!***



## **Utrecht – The Netherlands 1990**

**Bus garage with several CNG buses set into fire.**

- ✓ **No cylinder explosions**
- ✓ **Correct functioning PRD's**



# Real Accidents

**Brazil, 2003**

DIY range extension of a CNG car.  
The “mechanic” used a domestic  
LPG bottle. This bottle has a working  
pressure of only 30 bar and no PRD!



# *Real Accidents*

**Thailand, 2003**

**Vehicle converted into CNG with an Acetylene bottle (working pressure circa 60 bar). The car exploded at the second filling.**



# *Real Accidents*

## **Recklinghausen – Germany, 2000**

**Car mechanic refuels its LPG car at a CNG filling station. He used a “self-made” adapter. Working pressure of LPG tank is only 30 bar.**

**The same happened in Emmendingen – Germany circa five months before.**

**The driver thought : “*Gas is Gas*”**



# Real Accidents

**Göteborg, Sweden 15-01-2010**

Truck driver from Lithuania refuels its LPG bottle for his truck based “kitchen” at a CNG filling station.

He used a self-made adapter. Only after a couple of tries he was able to start filling.



Picture : Pontus Lundahl / Scanpix

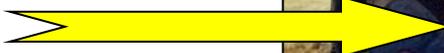


# Real Accidents

**Stockholm, Sweden 29-01-2010**

**Driver refuels its LPG car at a CNG filling station.  
He used a “self-made” adapter.**



**LPG Ringtank**   
**(working pressure 30 bar)**

# Instructions at CNG refuelling station

Instructions at a CNG refueling station in Germany and Austria to warn drivers for the differences between LPG and CNG

Must be multi-lingual

Must be very clearly placed at different places at the filling station

Nur für  
**Erdgas**

(200 bar, 20 MPa)

natural gas (CNG)

aardgas

gaz natural (GNV, GNC)

metano

gaz ziemny

природный газ

(рабочее давление 200 ат)

Nur für Erdgas-Fahrzeuge.

Use only for CNG/natural gas vehicles.

Alleen voor voertuigen op aardgas.

Pour véhicules équipés au gaz naturel seulement.

Solo per veicoli a gas metano.

Tylko do samochodów na gaz ziemny.

только для транспортных средств перевозки природного газа.

Nicht für

**Autogas/  
Flüssiggas**

LPG

GPL

пропан

(рабочее давление 16 ат)

Nicht für Flüssiggas-Fahrzeuge.

Do not use for LPG vehicles.

Niet voor voertuigen op LPG.

Ne convient pas aux véhicules équipés GPL.

Non per veicoli a gas GPL.

Nie stosować do samochodów na LPG.

не для транспортных средств перевозки пропана.



***CNG is SAFE, .....***

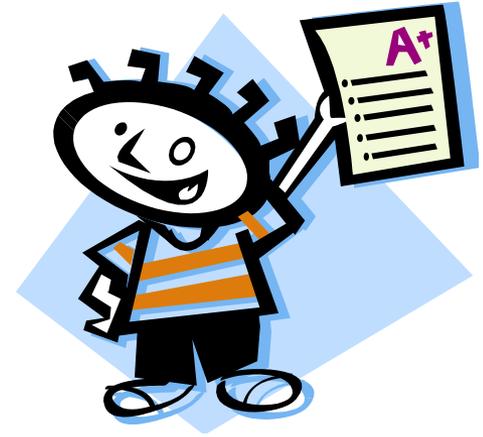


***CNG is SAFE, if you  
handle it SAFE !!***

# ***CNG is SAFE, if you handle it SAFE***

## **What to do ?**

- ✓ Training & certification of service station staff
- ✓ Training & certification of NGV drivers
- ✓ Training & certification of car mechanics
- ✓ Training fire fighters and rescue services
- ✓ Training customs at places where vehicles enter the country
  
- ✓ Clear multi-lingual instructions at filling station



Training can be provided by :

- ✓ Clean Vehicle Training Institute

[www.cleanvehicletaining.com](http://www.cleanvehicletaining.com)

# ***CNG Training & Consultancy***

***Available from :***

***RAP Clean Vehicle Technology***

[www.rap.ac](http://www.rap.ac)



***Clean Vehicle Training Institute***

[www.cleanvehicletaining.com](http://www.cleanvehicletaining.com)



***Thank you !***



***For further information :***

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# RAP Clean Vehicle Technology

➤ **Over 20 years experience in vehicle fuels**

- ✓ LPG, CNG, Biogas, LNG, Hydrogen
- ✓ Worldwide active

➤ **Training**

- ✓ Technical
- ✓ Safety
- ✓ Commercial

➤ **Consultancy**

- ✓ Technical
- ✓ Safety
- ✓ Commercial

➤ **Sales**

- ✓ **x**perion Transportunits for CNG & Biomethane

➤ **Co-founder of Clean Vehicles Training Institute**

➤ **Export Manager Eurogas Autogas Systems**



**NGV & H<sub>2</sub>V Training for Fire Brigades**



**Tractor converted to Dual-Fuel Biogas**

**x- STORE ADR/TPED Trailer**



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