Clean Cities Transportation

Workshop for Almaty

NGVs in their Global Context: Opportunities, Challenges, & Strategies

Almaty, Kazakhstan

30-31 March 2011

Dr. Jeffrey M. Seisler, CEO

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WHAT IS NATURAL GAS?

- **Mostly CH4: Methane**
  - **Gaseous @ atmospheric & high pressure**
  - **Liquefied @ ~ -163ºc**
  - **130 Octane**
- **Liquefied Petroleum Gas (LPG) is *NOT* natural gas**
  - **Propane & Butane**
  - **Liquid @ 15 bar**
  - **Gas @ atmospheric pressure heavier than air**
  - **110 Octane**

METHANE CAN ALSO BE A RENEWABLE FUEL

- ***Natural gas*, the fossil fuel is comprised mostly of methane (CH4) (the *old* gas molecule)**
- ***Biogas* derived from waste materials (plant, animal, human or urban waste) through anaerobic digestion (the *new* gas molecule)**
- **Synthetic gas (syngas) transforms waste through thermal gasification**
- **Biogas commonly is used to fuel electric generators, but can be upgraded and used in vehicles as *biomethane.***

HISTORICAL PERSPECTIVE RETROFIT & OEMS

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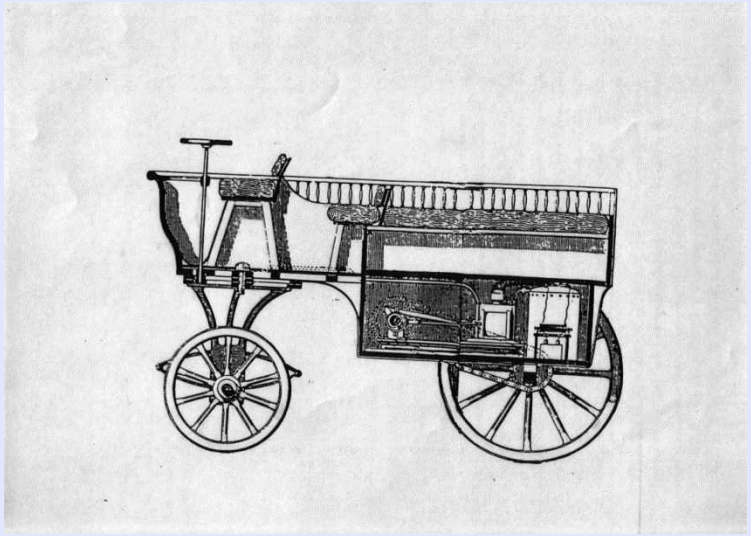
Natural Gas Vehicles History



The first internal combustion engine vehicle, a single cylinder, two stroke engine running on coal gas (methane).

Inventor: French/Belgian engineer Jean Joseph Etienne Lenoir 1860

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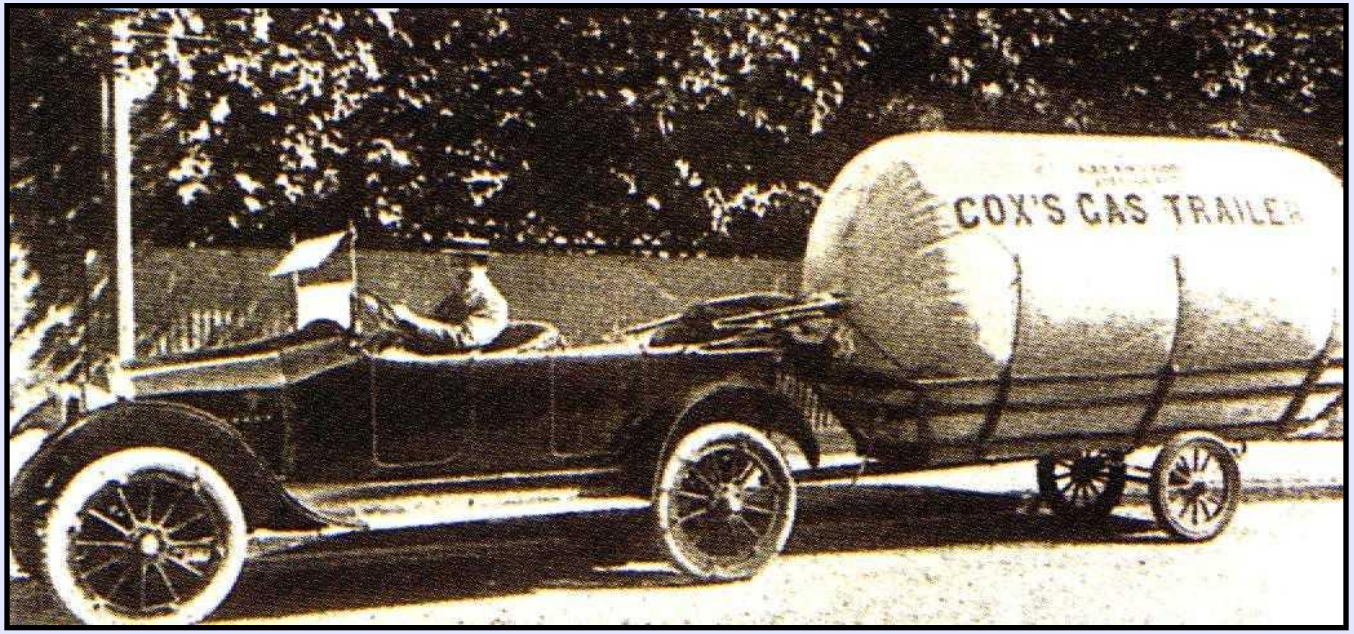
Natural Gas Vehicles History



Low-pressure fuel bag carried on a trailer (early 20th century)

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VINTAGE NGVs

Bus with Coal Gassifier

Adler-Diplomat – 1939
Coal Gas Conversion

Citroën Diesel-Gas (?)

THE Classic VW
Beetle (1939)

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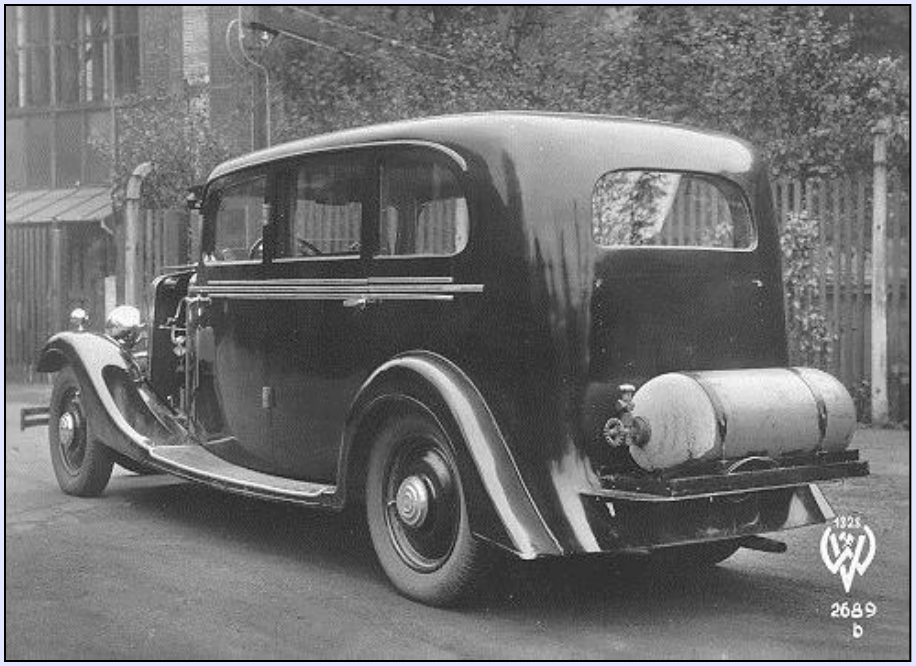
NGV Classics



Czech passenger car Wikov running on compressed town gas – around 1936

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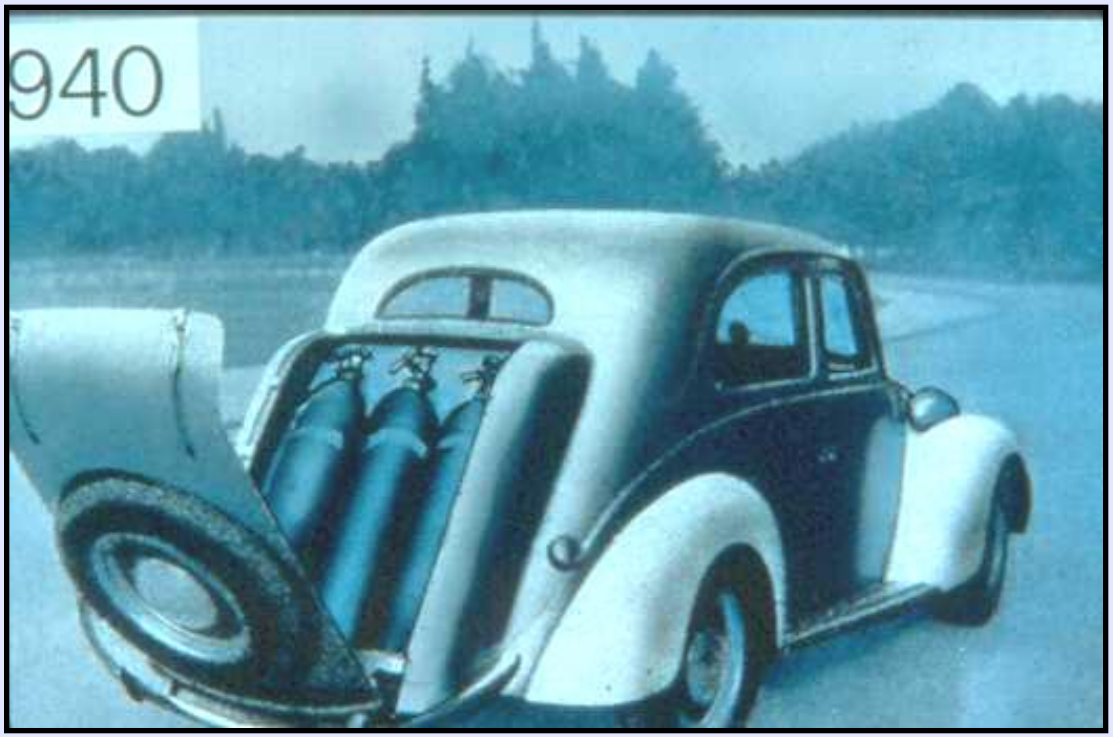
Natural Gas Vehicles History



1940's : High-pressure bottles inside the car

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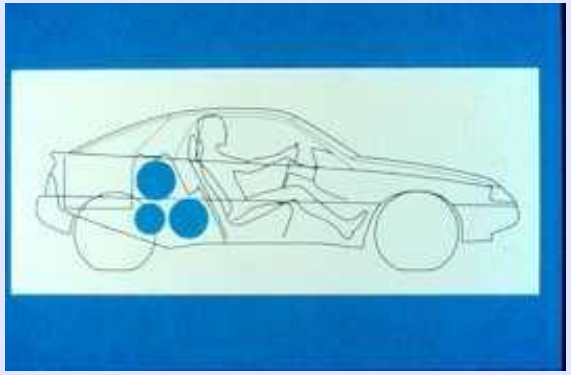
FORD PROOF of CONCEPT & PROTOTYPE NGVs



1983: Ford Concept NGV

Crown Victoria Dedicated NGV 1990

First of 24 Ford Ranger Prototypes

Dedicated NGV

1984

Rally for Fuel Savings 1984

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THE FIRST FACTORY BUILT NGV PROTOTYPE: EUROPE

Bi-Fuel BMW 518 & 316

1994

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Natural Gas Vehicle History (China)

1984: Low-pressure gas bags carried on the roof (China)

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HOW DO THEY WORK?

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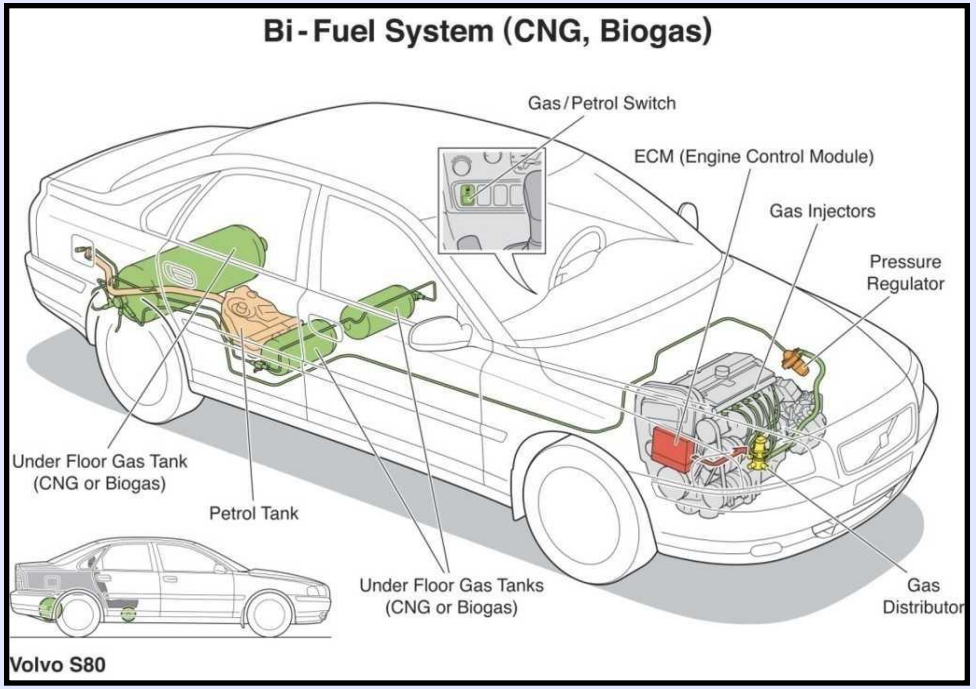
Typical bi-fuel CNG system: Light Duty Vehicle

- **Typical CNG Components in a Natural Gas Vehicle**

- **Standard internal combustion engine**
- **Compressed gas is stored in special fuel tanks**
- **Gas enters engine in its normal state as a vapor**
- **Car operates on natural gas OR gasoline**
- **Vehicles can be made to run on natural gas only**



Source : Volvo

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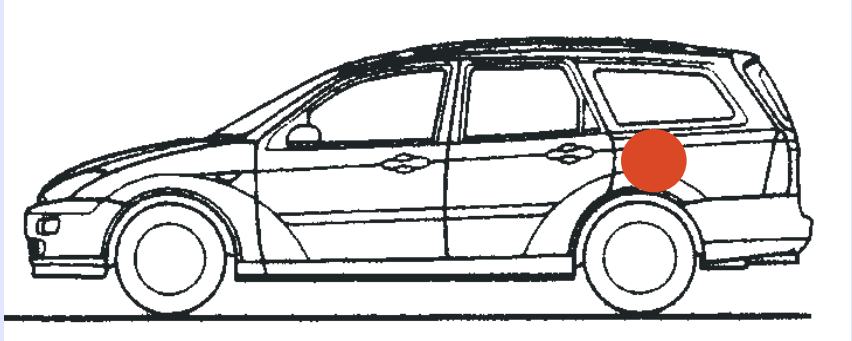
Typical CNG tank-mounting Light-Duty



One 80 liter type 1 tanks in passenger car; *range CNG ca. 175 km*

Two pieces type 1 tanks
of 70 liter each, mounted in a van;
range CNG ca. 200 km

Two pieces type 3 tanks
mounted under vehicle body;
range ca. 275 km

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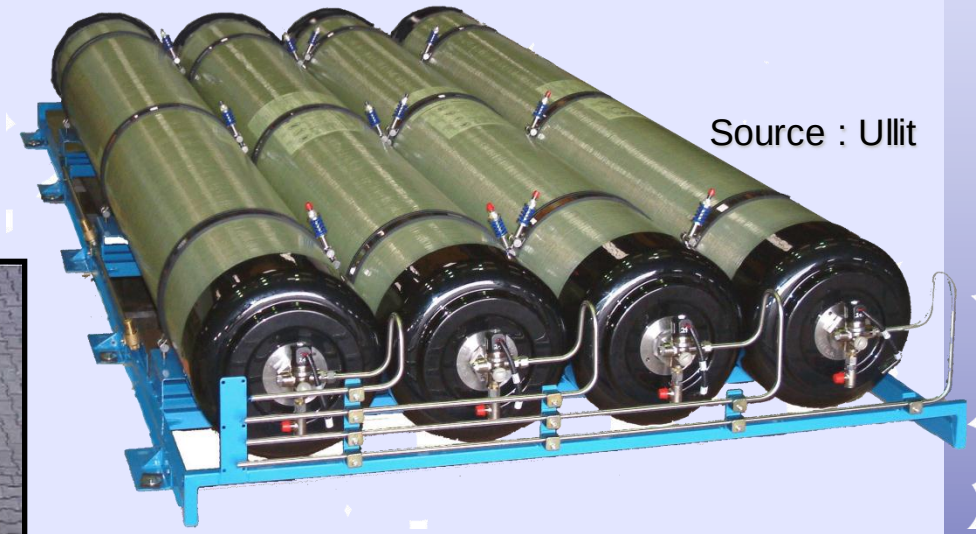
Typical CNG tank-storage Heavy-Duty

Eight pieces type-1 tanks of 80 liter each mounted onto chassis for garbage truck application

Source : DCAG



Source : Ullit

Four pieces type-4 tanks of 310 liter each mounted on roof for bus application

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NATURAL GAS FUELLING OPTIONS

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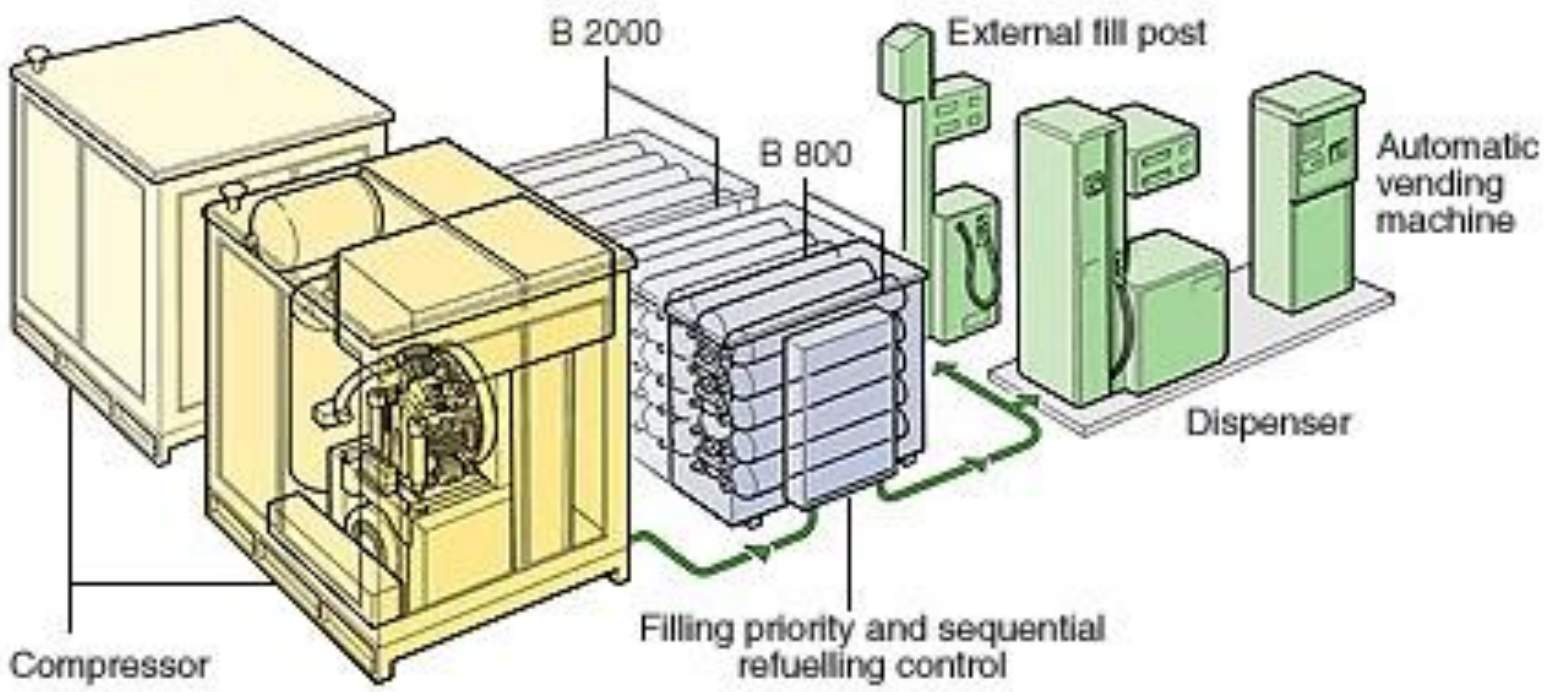
TYPICAL CNG FUELLING SYSTEM



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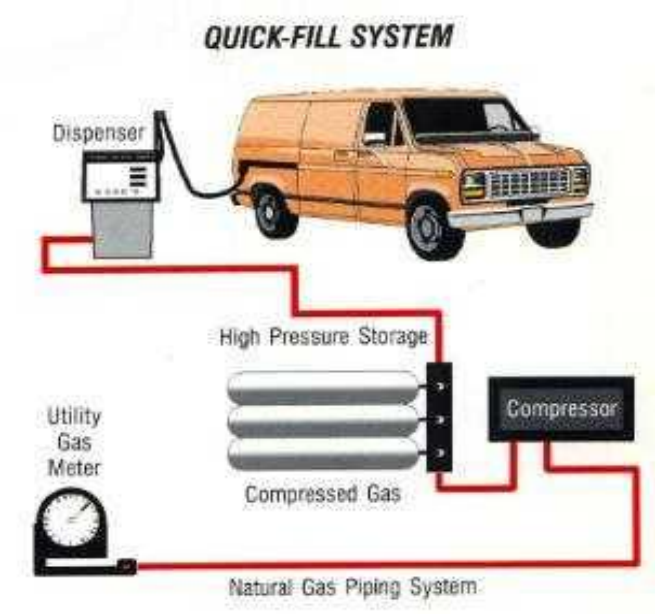
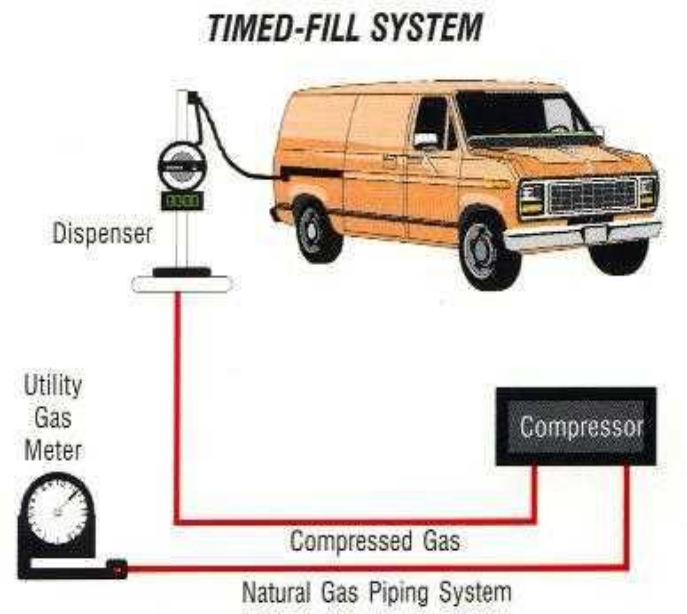
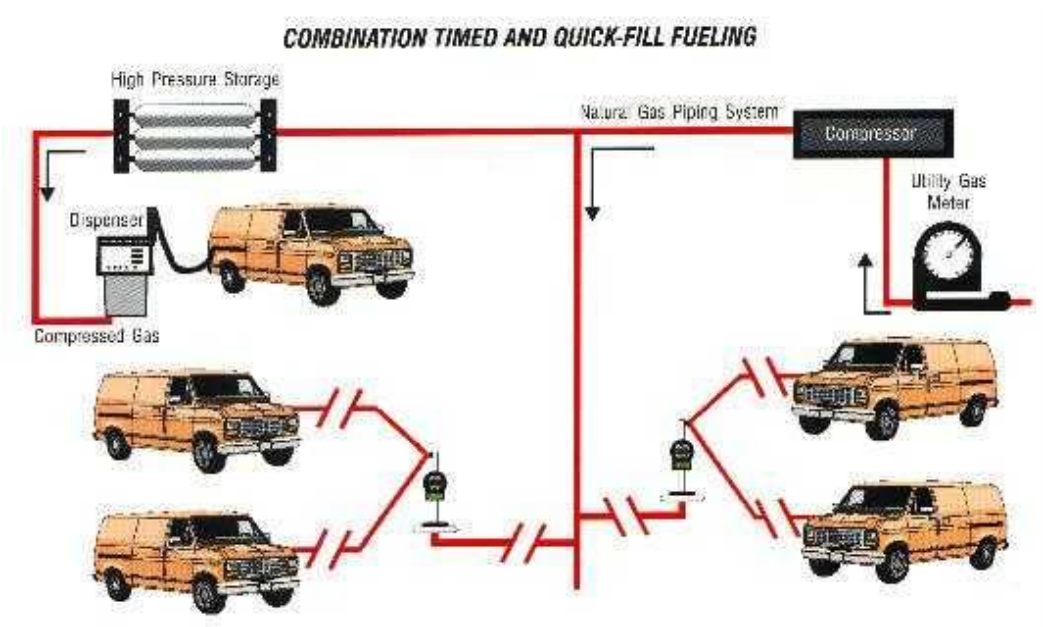
Fuelling Stations:Gaseous Fuels







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WORLD OVERVIEW

NGVs IN THEIR GLOBAL CONTEXT

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NGVs IN THE WORLD 2011

World Total

~ 13.2 M | 18.893 | 1805

Italy
754.659

Europe (incl. IT & RU)
1,377,777

Russia
100.053

Canada
14.205

USA 110.000

Iran
2.070.930

Pakistan
2.850.500

China
550.000

Japan
38.623

Egypt
139.804

India
1.100.000

Thailand.
231,753

Venezuela
43.000

Colombia 340.000

Brazil
1.661.919

Bolivia 140.000

Australia
2.453

Argentina 1.918.404

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Data source: The GVR, January 2011

NGVs | Fuelling Stations (FS) | FS Under construction

01.2011

THE TOP TEN NGV COUNTRIES WORLDWIDE

Country	NGVs	Fuel Stations	% Price Nat.Gas *of* Petrol*
Pakistan	2,850,500	3,300	**42%**
Iran	2,070,930	1,574	**60%**
Argentina	1,918,404	1,882	**63%**
Brazil	1,661,919	1,787	**36%**
India	1,100,000	600	**59%**
Italy	754,659	831	**49%**
China	550,000	1,652	**39%**
Colombia	340,000	614	**47%**
Thailand	231,753	433	**81%**
Ukraine	200,019	283	**53%**
Bangladesh	200,000	600	**64%**

•US$/Liter vs 1 Nm3 gas

Data source: The GVR, January 2011

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The Top Ten NGV Countries Worldwide
% NGVs of *All* Vehicles

Country	NGVs	Total vehicle population	% NGVs of All Vehicles
Pakistan	2,850,500	3.3 mil	**81.5%**
Iran	2,070,930	12.2 mil	**17%**
Argentina	1,918,404	12.6 mil	**15%**
Brazil	1,661,919	35.1 mil	**4.7%**
India	1,100,000	14.6 mil	**7.5%**
Italy	754,659	40.9 mil	**1.8%**
China	550,000	42.6 mil	**1.2%**
Colombia	340,000	2.9 mil	**11.6%**
Thailand	231,753	10.1 mil	**2.3%**
Ukraine	200,019	7.6 mil	**2.7%**
Bangladesh	200,000	293,472(?)	**61%(or 30%)**

- **US$/Liter vs 1 Nm3 gas**

Data source: The GVR, January 2011

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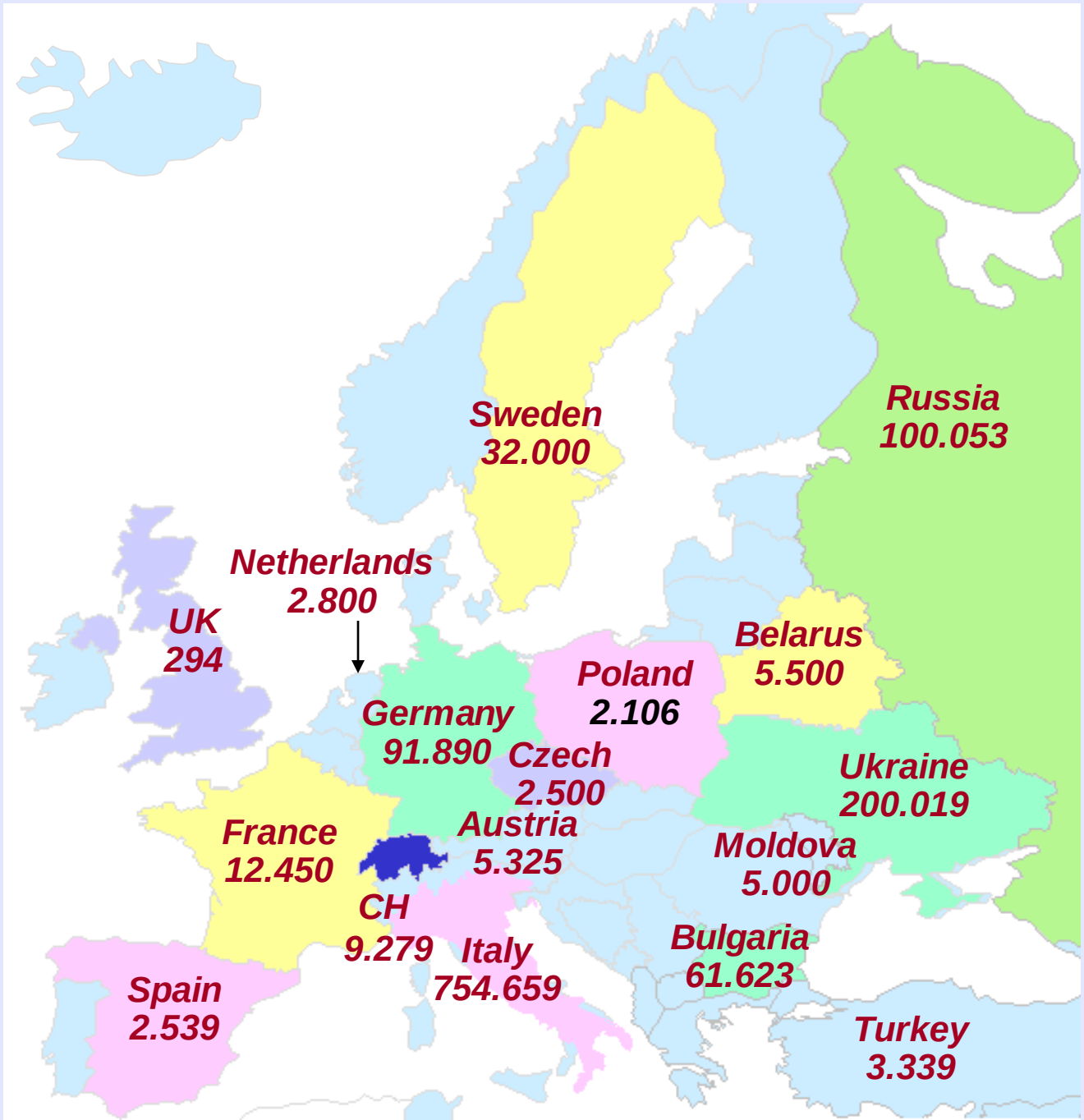
NGVs in EUROPE

Europe Total
~ *1.452.798*
NGVs
Refuelling Stations
~ 3,740



Data source: The GVR, January 2011

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Natural Gas Buses Medium & Heavy Duty Worldwide
Top 10 Countries*

COUNTRY	TOTAL NGVs	NAT.GAS BUSES	% OF NGV FLEET
CHINA	550,000	150,000	27%
UKRAINE	200,019	120,000	60%
KOREA	28,324	25,390	90%
INDIA	1,100,000	23,000	.02%
MYANMAR	42,000	18,290	44%
COLOMBIA	340,000	13,800	4%
THAILAND	231,753	13,420	6%
USA	110,000	11,000	1%
ARMENIA	101,352	9,831	10%
BANGLADESH	2, 070,930	5,364	.003%
WORLD TOTAL	**13,195,624**	**413,957**	.03%

*Data source: Gas Vehicles Report, January 2011

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GROWTH RATES 2006-2010

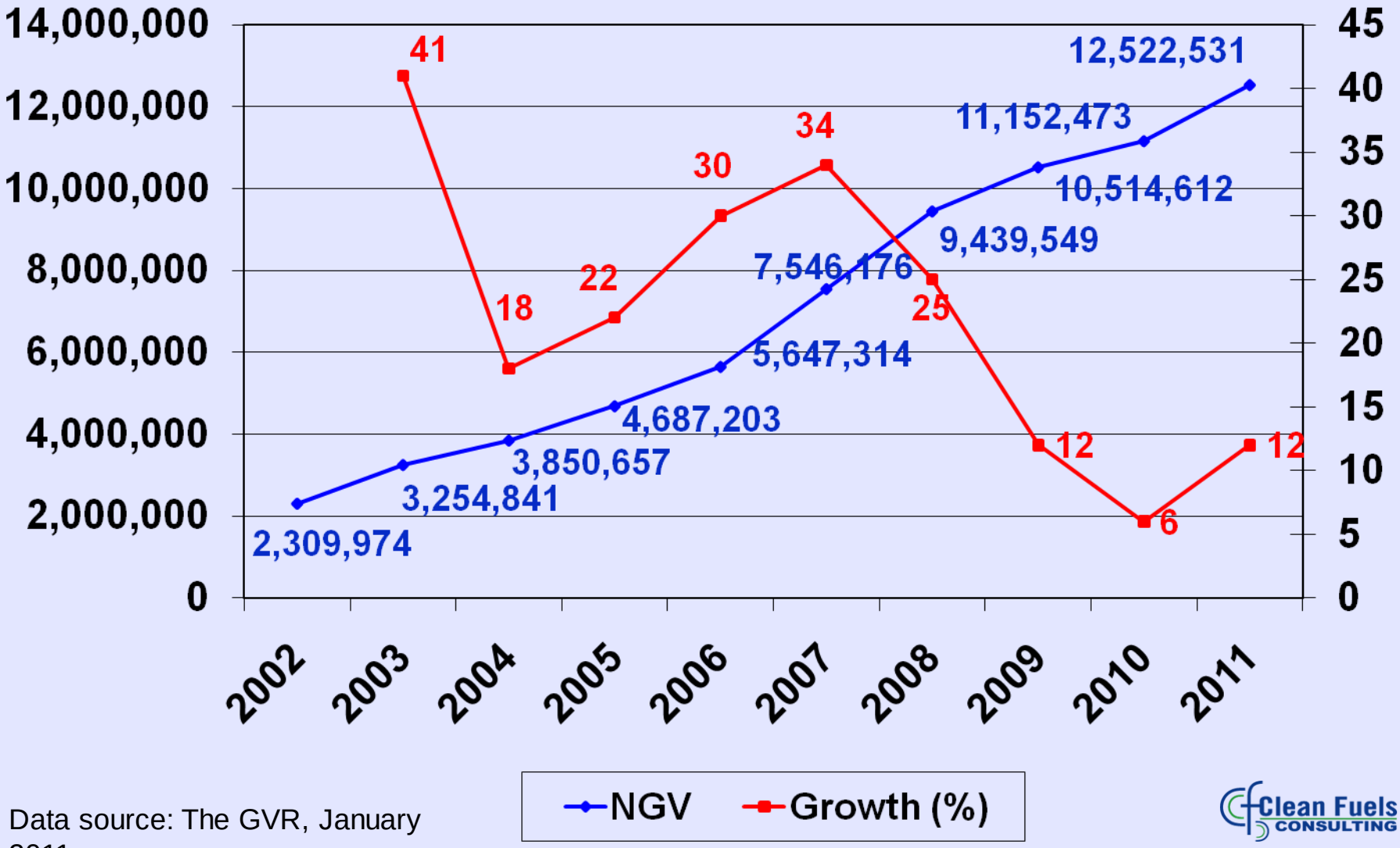
(January 2011)

	2006	2010	%
WORLD	4.6 Million	12.5 Million	172%
CHINA	97,200	500,000	414%
BRAZIL	1 Million	1.6 Million	60%
EUROPE	556,000	1,452,798	161%
UKRAINE	67,000	200,000	199%
ITALY	382,000	676,850	77%

Data: Gas Vehicles Report

World NGV Growth

Vehicle Numbers & % Growth Rate



Data source: The GVR, January 2011

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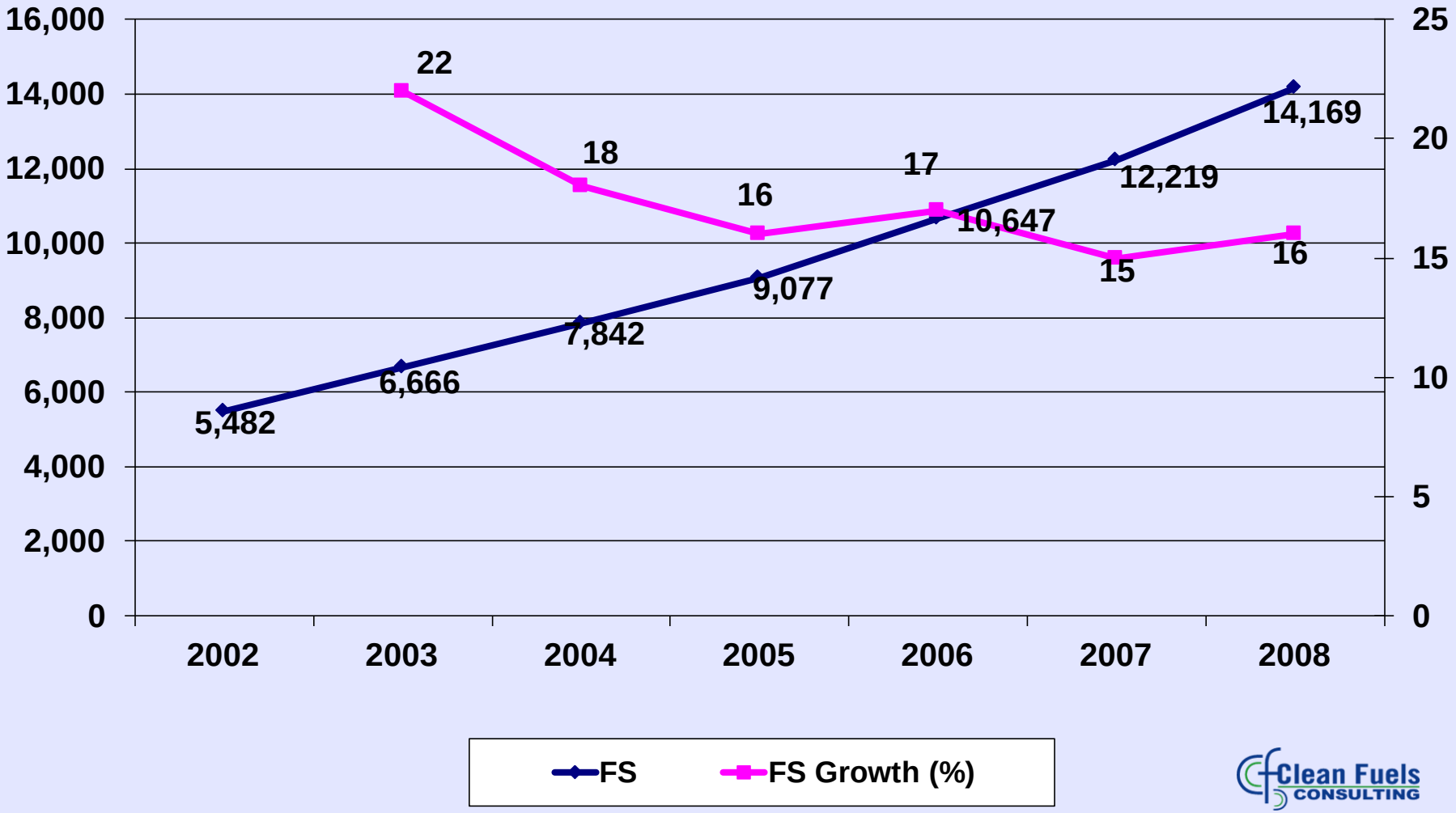
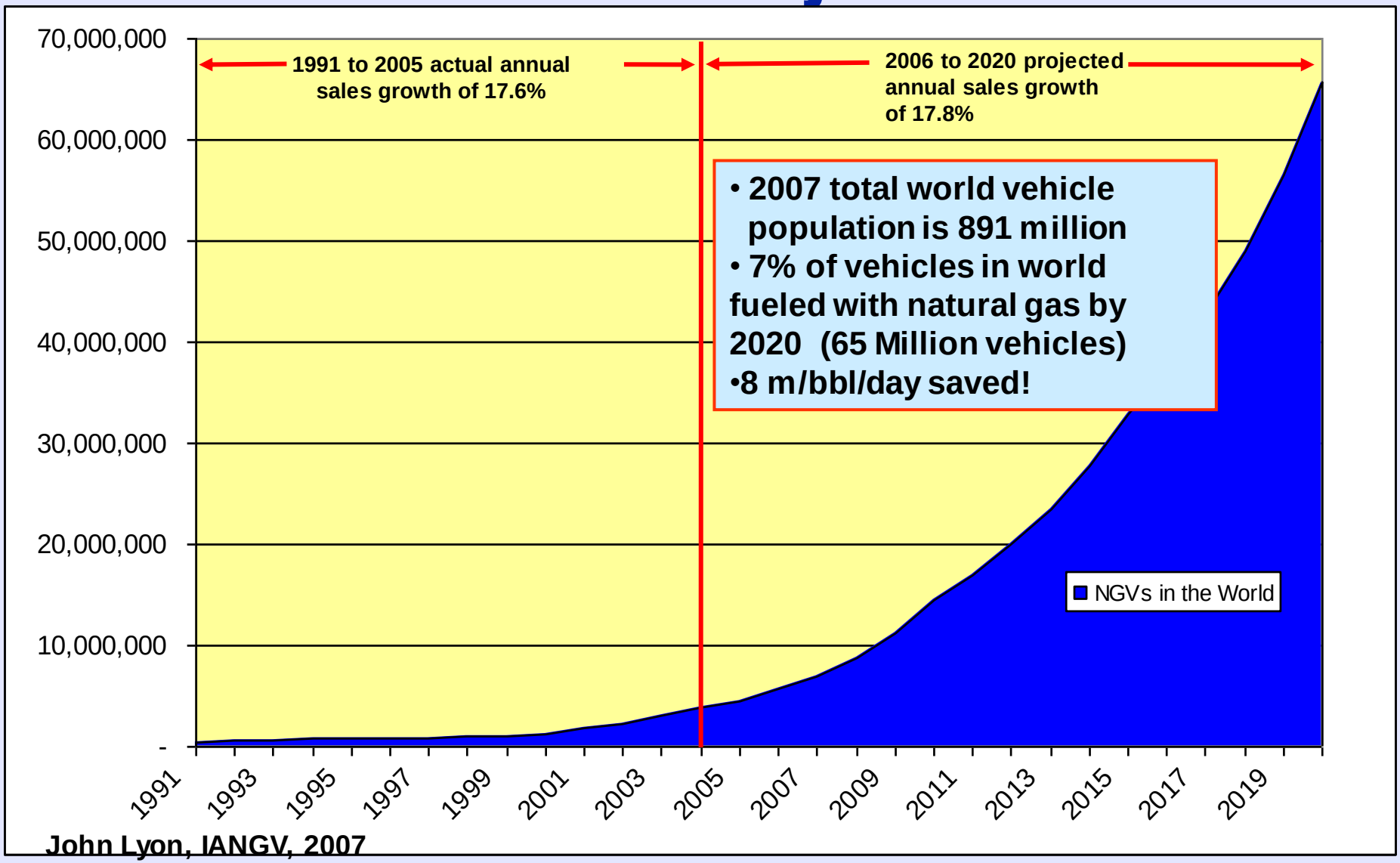
World Fuelling Station Growth

Station Numbers & % Growth Rate



Data source: The GVR, April 2009

World Wide NGV Growth Actual/Projected



John Lyon, IANGV, 2007

WHY NGVs?

- Economical
- Environmentally friendly
- Safe
- Long term energy supply & excellent delivery network worldwide
- Technology is available

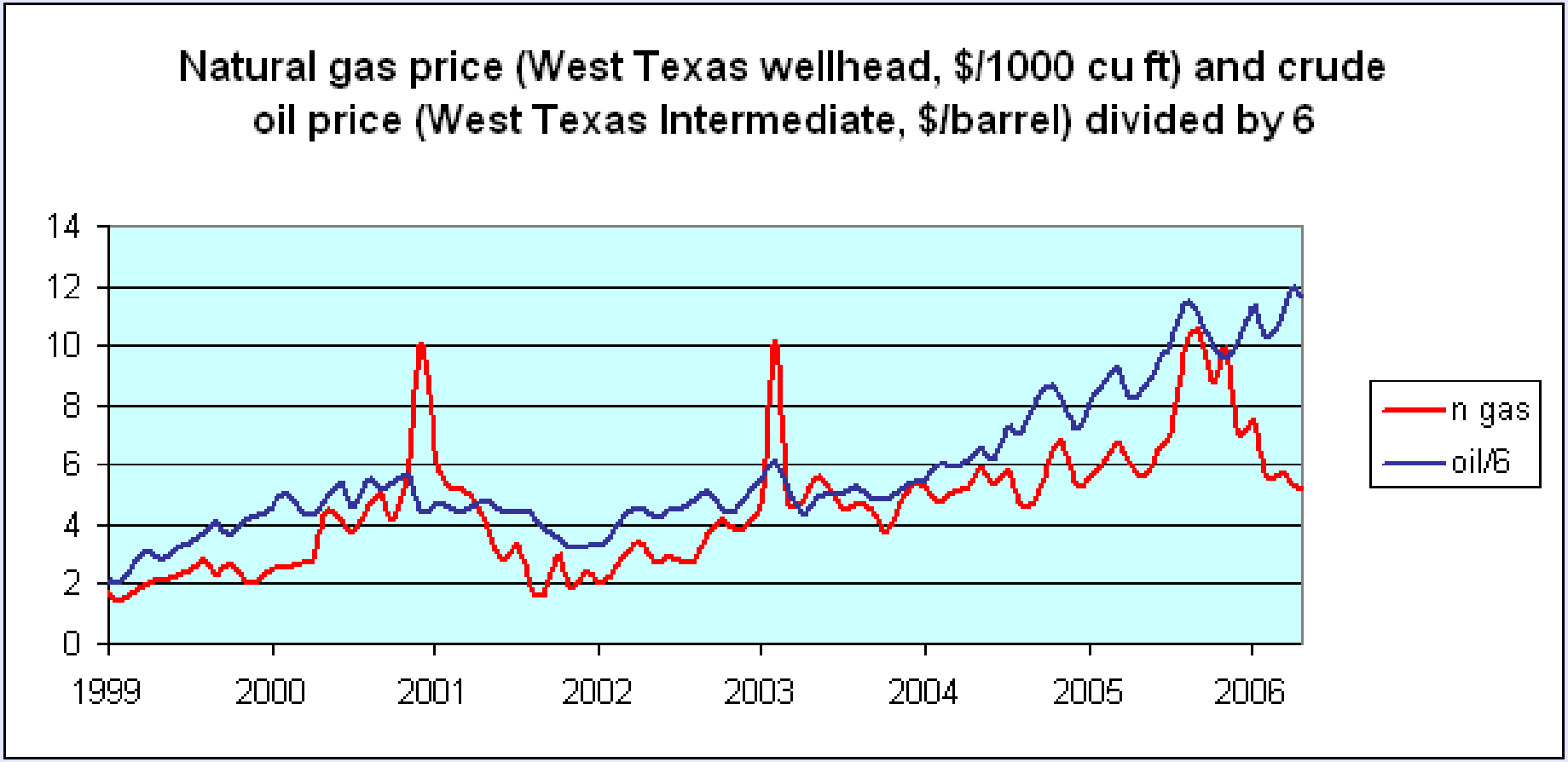
NGV Economics

- **Fuel Cost**
- *Typically natural gas is 30-50% cheaper than gasoline and diesel (also depends on taxes)*
- *Fuel price savings offsets higher first cost of vehicle*
- **Vehicle Cost**
- *All alternative fuel vehicles (AFVs) cost more than gasoline/diesel (unless subsidized by the manufacturer)*
- *NG cars typically are $2000-$5000 or more than gasoline vehicles*
- *Conversions are less depending on market: $800+*
- *Trucks and buses can be $30,000-50,000+*

PRICE OF NATURAL GAS & OIL

Natural Gas Typically Tracks Below Oil

(energy equivalent basis)



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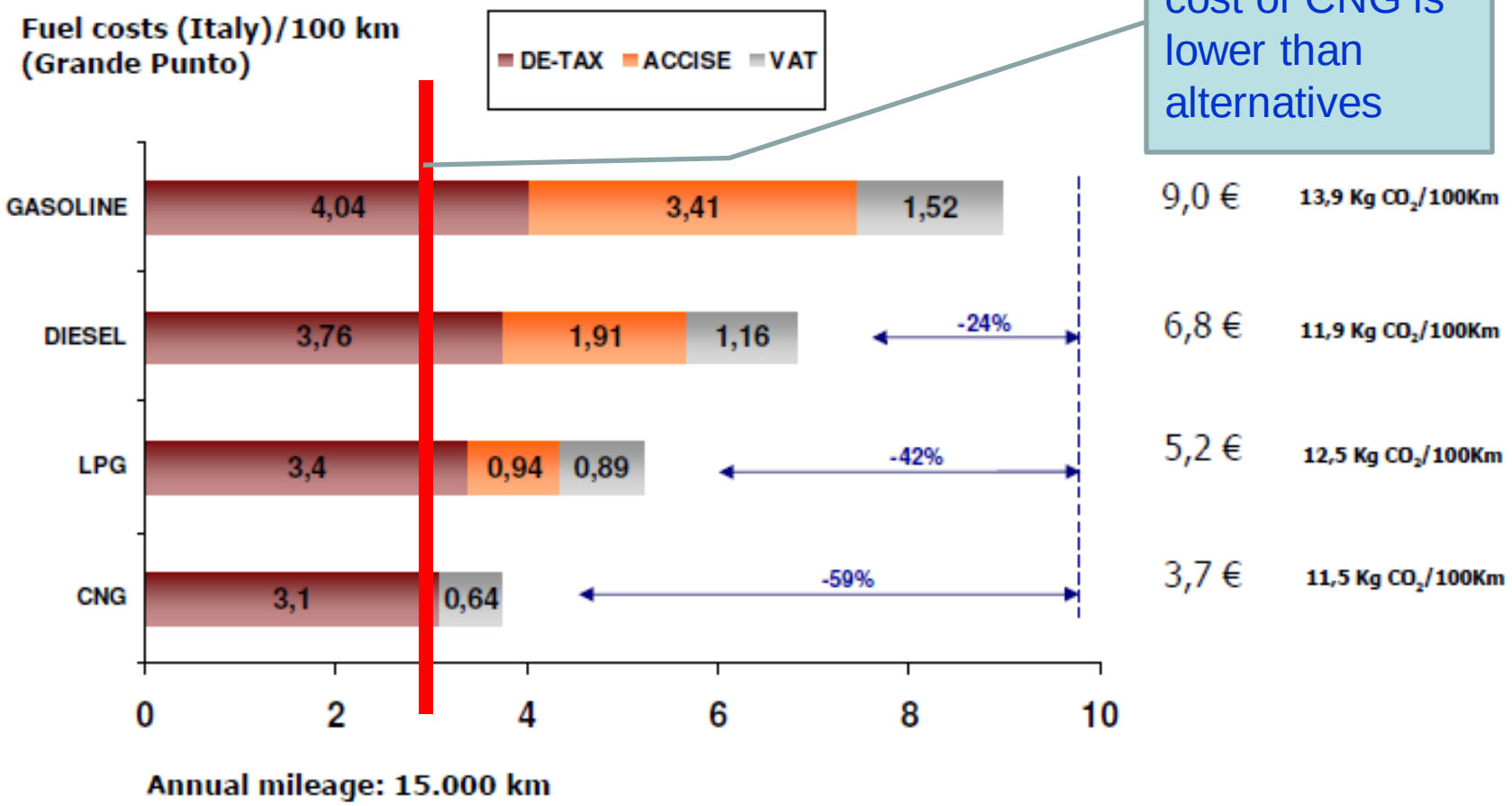
NGV Running Costs: Italy

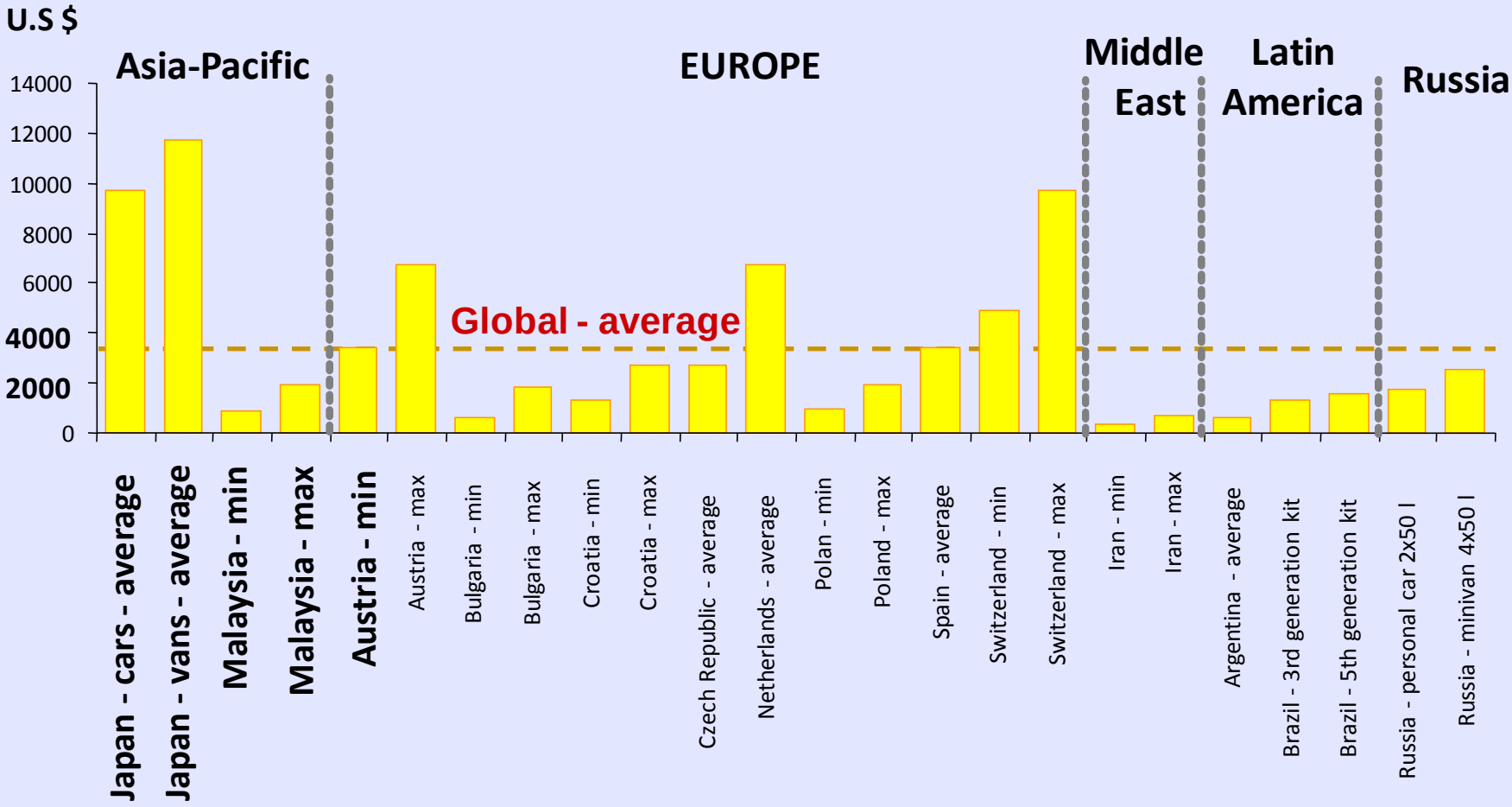
Vehicle tax policies play an important role!



The energy cost of CNG is lower than alternatives

Adapted from M.Ziosi, Prospects fior the Development and Use of CNG in Transport: Italy, (Promoting the Uptake of Gaseous Vehicle Fuels, Biogas and Natural Gas, in Europe GasHighWay,)1.2.2010

Worldwide (outside USA) Average* NGV conversion costs - LDVs



***NOTE: Highly dependant on type of equipment; cylinder volume, type and number; new or recycled components; approvals and certification etc.**

Prices of alternative fuels on an energy equivalent basis (U.S. case, July 2010)

	Nationwide Average Price in Gasoline Gallon Equivalents	*Nationwide Average Price in Diesel Gallon Equivalents*	*Nationwide Average Price in Dollars per Million Btu*
Gasoline	$3.08	$3.43	$26.67
Diesel	$3.09	$3.45	$26.81
CNG	$1.93	$2.15	$16.74
Ethanol (E85)	$3.89	$4.33	$33.68
Propane	$4.22	$4.70	$36.54
Biodiesel (B20)	$3.19	$3.56	$27.67
Biodiesel (B99-B100)	$3.99	$4.45	$34.57

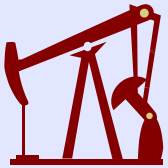
Clean Cities Alternative Fuel Prices Report, U.S. Department of Energy January 2011

NGVs are Environmentally Friendly

- **Proven better for smog, particulates, and ozone**
- **Global warming emissions (CO2 & CH4) are reduced by 20-25% in cars**
- **GHG emissions on par with diesel but will improve to about 15% less than new generation of diesel engines**

EMISSIONS BENEFITS OF FUELS

- **Regulated emissions comparisons (NOx; CO; Hydrocarbons (HCs); Particulate Matter (PM)**
- **Unregulated emissions also are very important!!**
  - **Toxics**
  - **Carcinogens**
  - **Nano-particulates**
- **Well-to-Wheel comparisons are important, very complex but depend on the model's *assumptions***
  - **Single vehicle (LDV) must be used, so generalization to HDVs is not necessarily appropriate**
  - **Well-to-tank analysis can be reliable for all vehicles**



UNDERSTANDING EMISSIONS IMPACTS OF FUELS

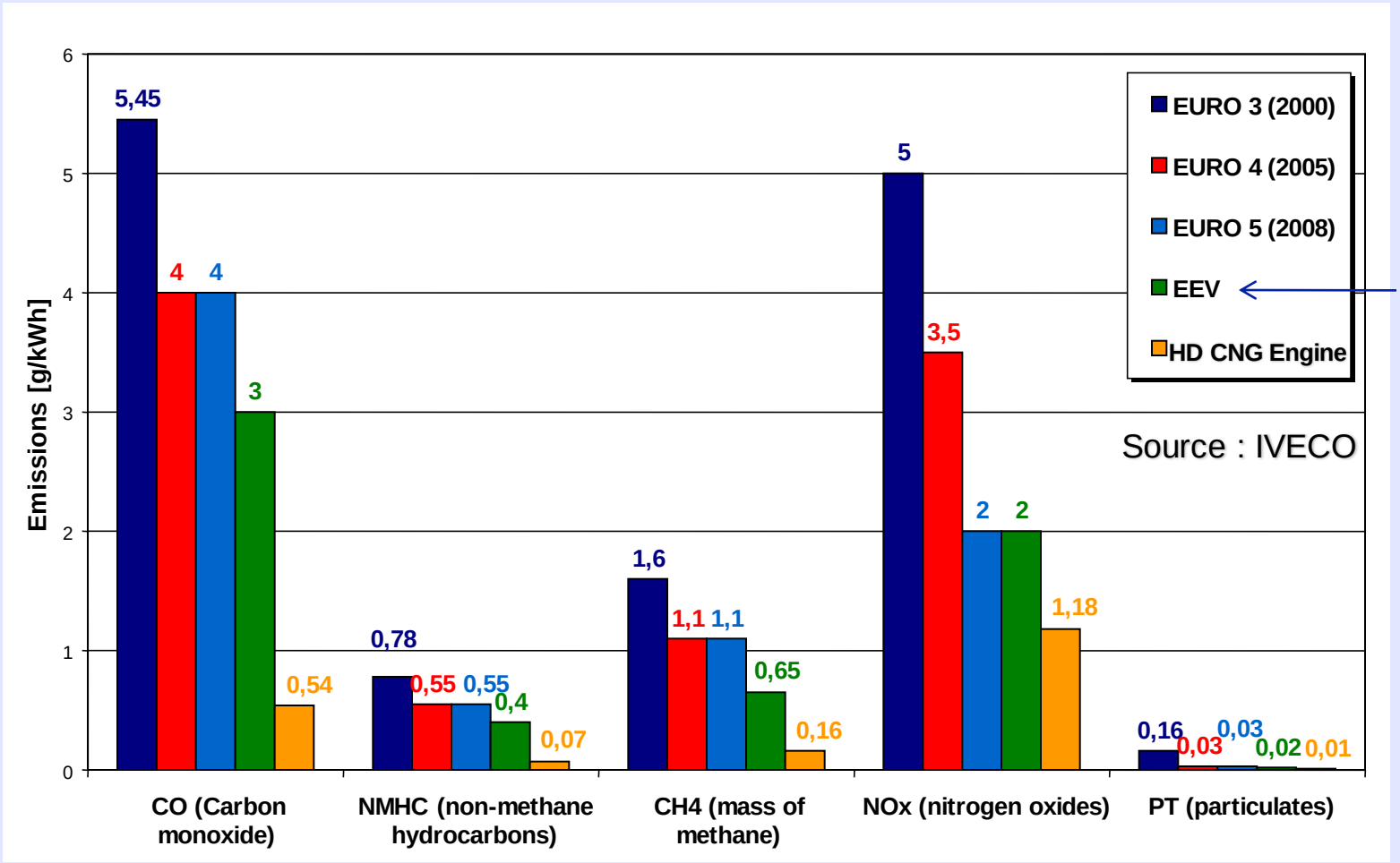
- **Regulated emissions (NOx; CO; Hydrocarbons (HCs); Particulate Matter (PM)**
- **Unregulated emissions also are very important!!**
  - **Toxics**
  - **Carcinogens**
  - **Nano-particulates**
- **Well-to-Wheel comparisons are important, very complex but depend on the model's *assumptions***

Emissions in energy production, transmission & distribution

WELL TO TANK | **TANK TO WHEEL (i.e. tailpipe)**

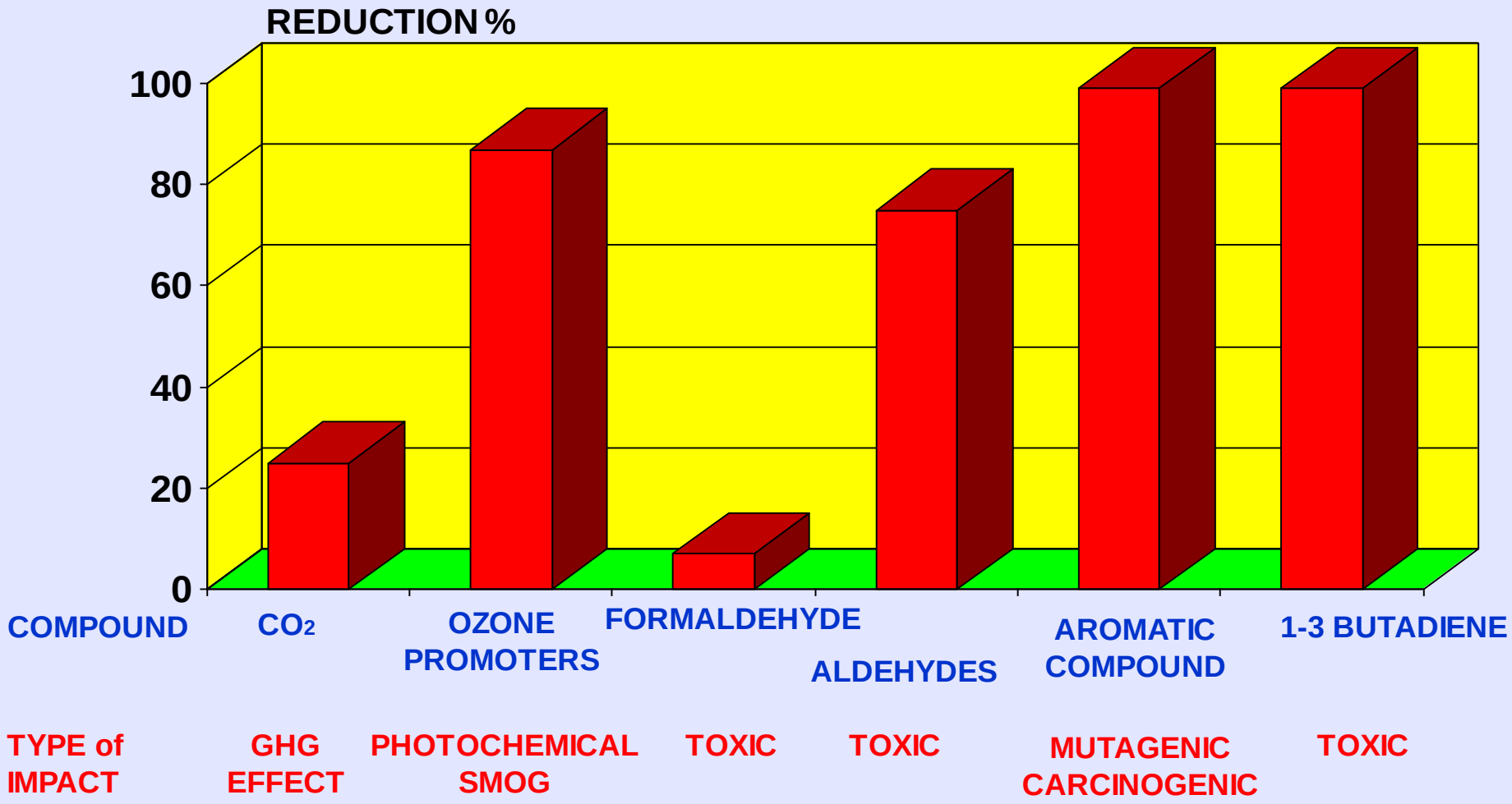
Regulated Emissions
Heavy-Duty Mono-Fuel Gas Engine
(stoichiometric engine)

Compared to Euro 3, 4, 5 & EEV limits



EEV = Environmentally Enhanced Vehicle (target values)

CNG/GASOLINE COMPARISON
UNREGULATED EMISSIONS



Source: FIAT Research Centre

WELL-TO-WHEEL ANALYSIS

Fig. 9: Well-to-wheels energy efficiency emissions of ICE and fuel cell vehicles (C-H2 based on NG, piped 4000 km)

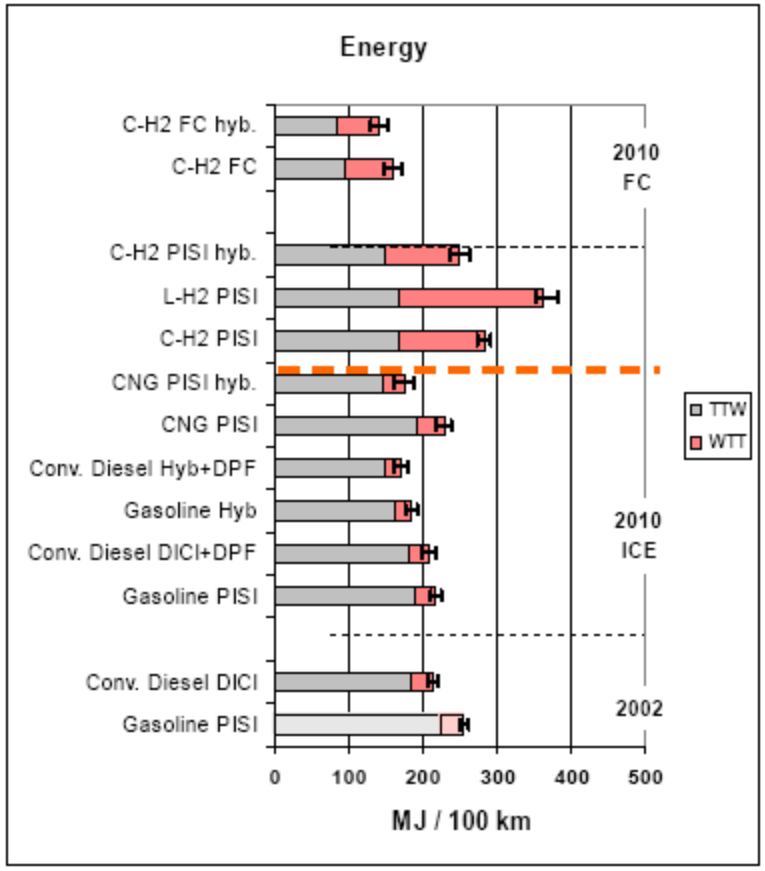
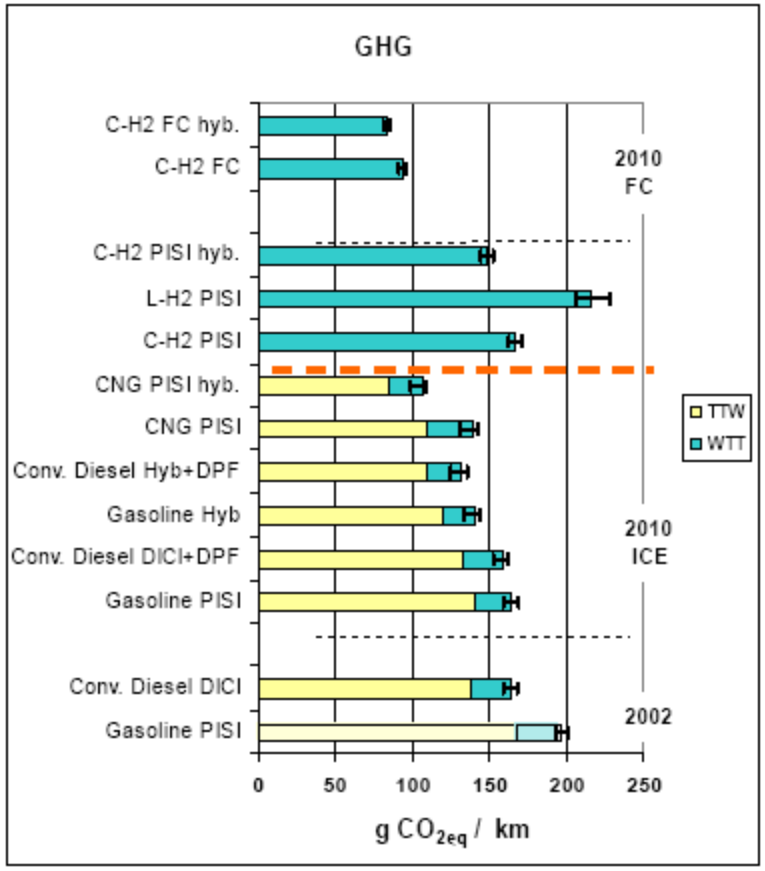
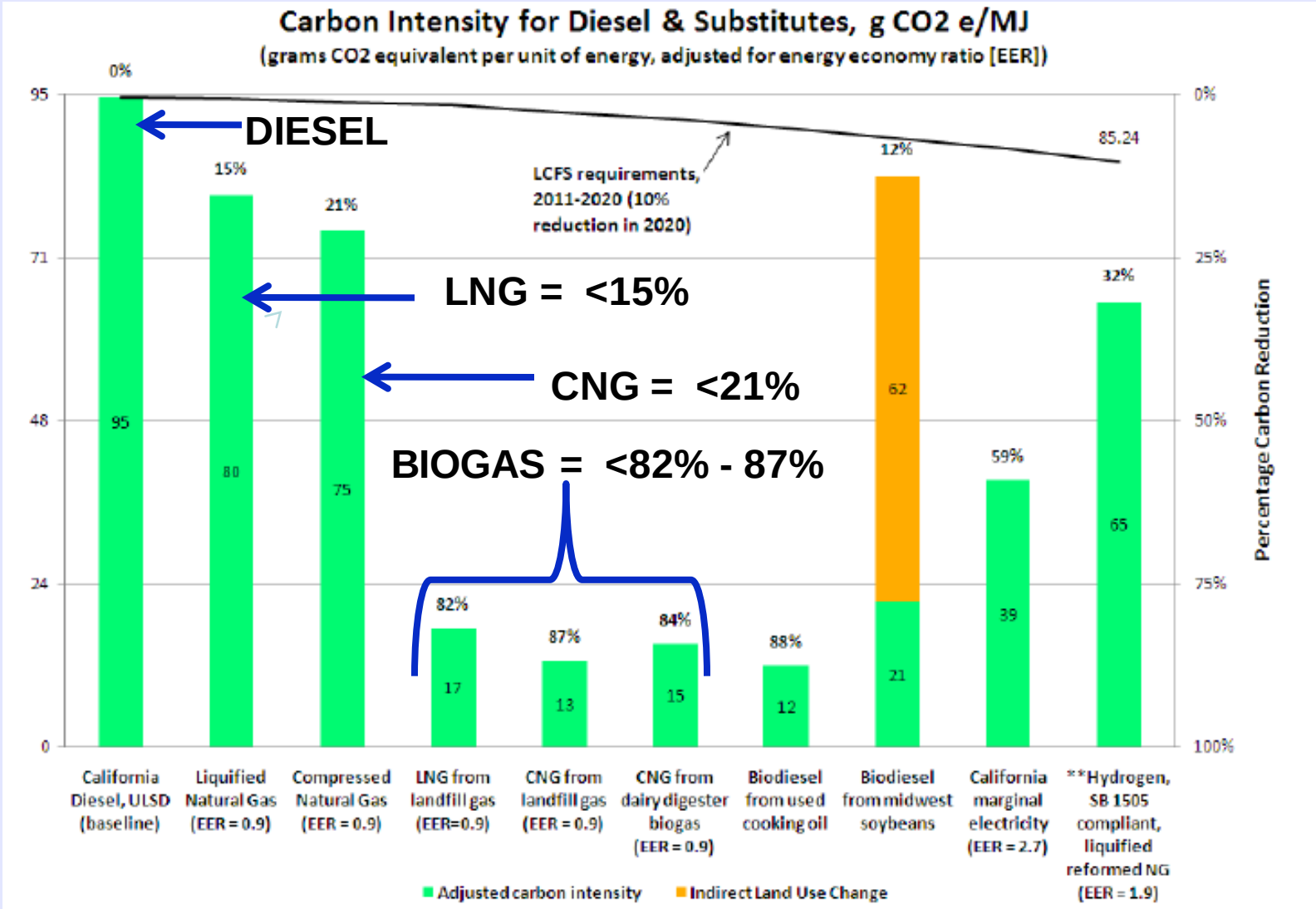


Fig. 10: Well-to-wheels greenhouse gas emissions of ICE and fuel cell vehicles (C-H2 based on NG, piped 4000 km)



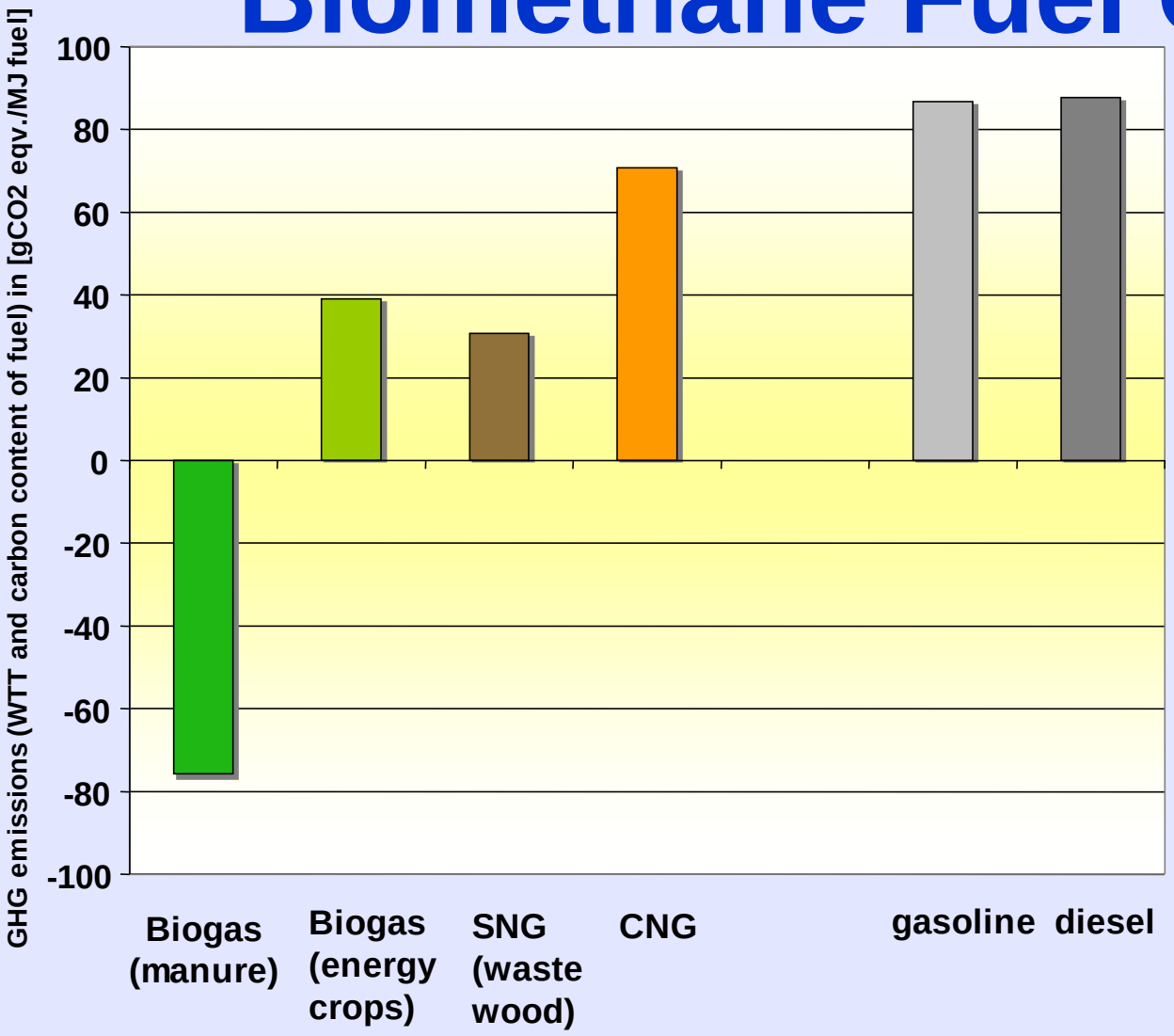
PISI: port injection, spark ignited DICI:direct injection, compression ignition DPF: diesel particulate filter

Carbon Intensity for Diesel & Substitutes



Source: California Air Resources Board LCFS. **Liquefied hydrogen is derived from ARB LCFS pathway document.

GHG Emission Reduction of Biomethane Fuel Chains



-GHG balance is dominated by biomass chain:

-Fermentation of liquid manure avoids CH_4 emissions of alternative manure disposal and, thus, receives high GHG bonus ⇨ negative GHG emissions (-187%)!

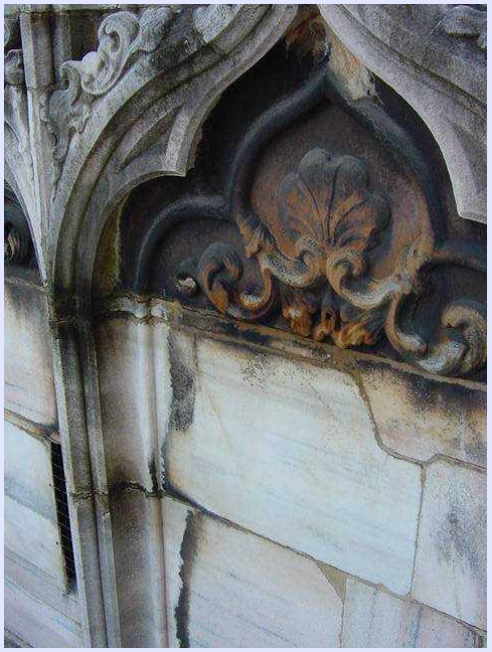
-Cultivation of energy crops induces energy use and GHG emissions (incl. N_2O) ⇨ net emission reduction (-55%) compared to fossil options

Source: Concawe/EUCAR 2003, Wuppertal Institute et al. 2006

Natural Gas is the Cleanest of Fuels

Milan Skyline from the Duomo—caused by *diesel & gasoline emissions*

Cleaning Pollution



NATURAL GAS HAS NO PARTICULATES

Dr. Otto Zach

Director of Energy Policy Division,

Austrian Ministry of Economics & Labour

In Brussels, April 2006

NATURAL GAS & NGVs ARE *VERY* SAFE

- **Natural gas is safe**
  - **Lighter than air & dissipates**
  - **Narrow flammability range (5-15% gas-air)**
  - **High ignition temperature**
- **Compressed gas fuel systems are *very* strong**

SAFETY:

CNG Cylinder Severe Abuse Test

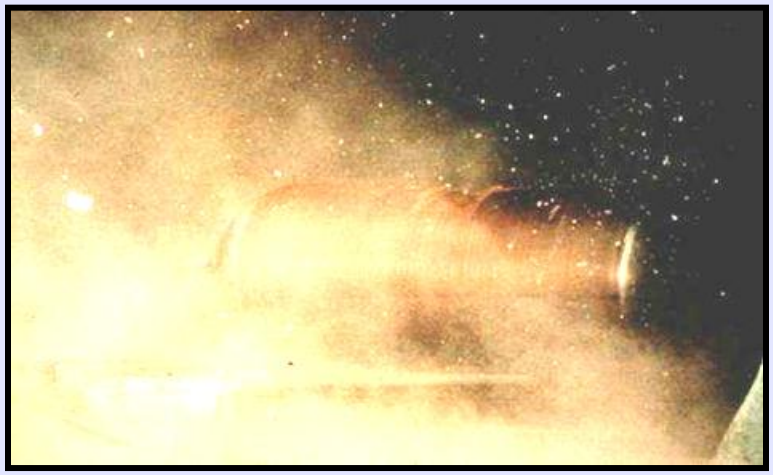
Only an armor-piercing bullet shot from a NATO-style assault rifle can penetrate a metal cylinder.

SEVERE ABUSE TESTING

Car drops from…
10 …17….23…30 meters and no leakage

NGV SAFETY:

Severe Abuse Testing of CNG Cylinders



Dynamite Test

Bonfire test

CNG cylinders remain intact under the most rigorous conditions

NGV SAFETY

Fire in a bus garage in Utrecht, Netherlands, 6th July 1990

The melt fuse has done a good job

Remains of the natural gas bus. All cylinders are intact; no explosions occurred

The valve melted away

SAFETY: Liquefied Petroleum Gas (LPG) (Propane & Butane) IS NOT CNG

A warning sign in Austria & Switzerland

Chongqing May 2006: Owner adds LPG tank to NGV

昨日，一牌照为渝A24494的奥拓车，在巴南区鱼洞路口加气站加气时，车载气瓶突然爆炸。

气瓶飞出百米远

李仁贵的水果摊距加气站至少百米。他称，10时15分左右，气站突传巨响。他抬头，一铁家伙呼啸着飞来，将水泥地砸一大坑——铁家伙就是气瓶，爆炸后只剩1/3残片。

气站内的人四散逃命，天然气味很快弥漫开来。李仁贵发现，一人趴在气站内奥拓车上。

消防、交警、120等相继到场。趴在奥拓车上的男子被送市七院；因空气中天然气浓度超标，消防出水稀释。

加气站负责人称，事发加气站当时还停有一长安面包车。爆炸时，奥拓车主在车尾，紧邻气瓶。加气员靠长安车遮挡，毫发未伤。长安车司机去厕所了，幸免于难。据称，加气前，工作人员对气瓶目测，其检测合格期至2007年1月。

奥拓车主受重伤

在市七院，医生称，伤者右手肘关节以下残缺，脑、胸部可能重创。伤者女儿称，老人姓蒋，61岁，平时喜欢玩车。这辆奥拓是几年前买的，去年实施"油改气"，具体是哪家公司改的？儿女均摇头。

巴南区商委有关人士说，目前尚无法确认事故源于气瓶质量，但"这是调查重点"，同时将深挖为奥拓车实施"油改气"企业的情况。

据悉，因现场一根通信电缆被砸，上百居民电话中断，相关部门正在抓紧抢修。

奥拓车已被炸得面目全非

车载气瓶爆炸系首次

我市"油改气"专家、市汽车研究所天然气汽车改装厂厂长郭文刚称，在近年大规模实施"油改气"以来，这是我市首例车载气瓶爆炸伤人事件。

郭称，气瓶爆炸原因很多，绝大多数属气瓶超期"服役"、罐体质量以及改装质量造成。他称，我市由市交委核准的"油改气"企业有8至9家，而无证企业不少。由于无证企业使用淘汰气瓶，成本低，很有市场。据悉，正规厂家"油改气"需花四五千元，而无证企业只需千余元。

郭介绍，我市出租车气瓶使用年限为15年。每两年需到市特种材料检测中心质检。他提醒说，只要"油改气"找正规厂家并定期质检，车载气瓶安全应有保障。

记者　朱亮/文　钱波　杨帆/图

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UKRAINE, JULY 2007

NGV installer cuts a cylinder and welds the end to make it short enough to fit into the car.

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Natural Gas is an abundant source of energy: fossil sources and renewable sources from biomass

Clean Fuels CONSULTING

FOSSIL NATURAL GAS IS AN ABUNDANT WORLDWIDE ENERGY SOURCE

- **Abundant Worldwide Gas Resources**
  - **Proven reserves to 2100; potential reserves to 2200**
  - **Vast potential from gas extracted from shale & in methane *hydrates* (ice) *(future)***
  - **Strong & growing distribution network (2.03 mil. km in Europe; 2.4 mil. *miles* in US [3.9m kms])**

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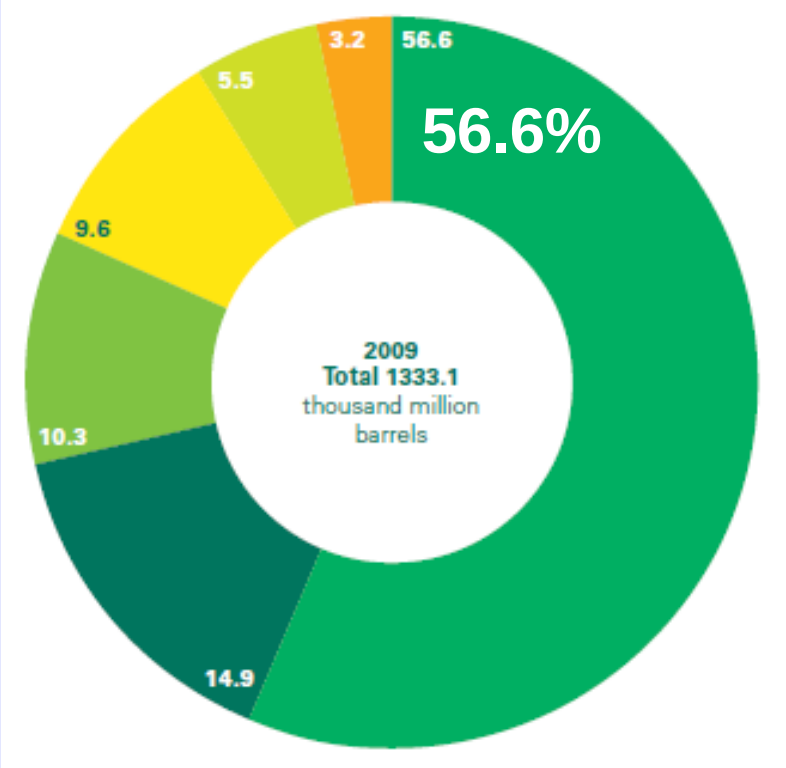
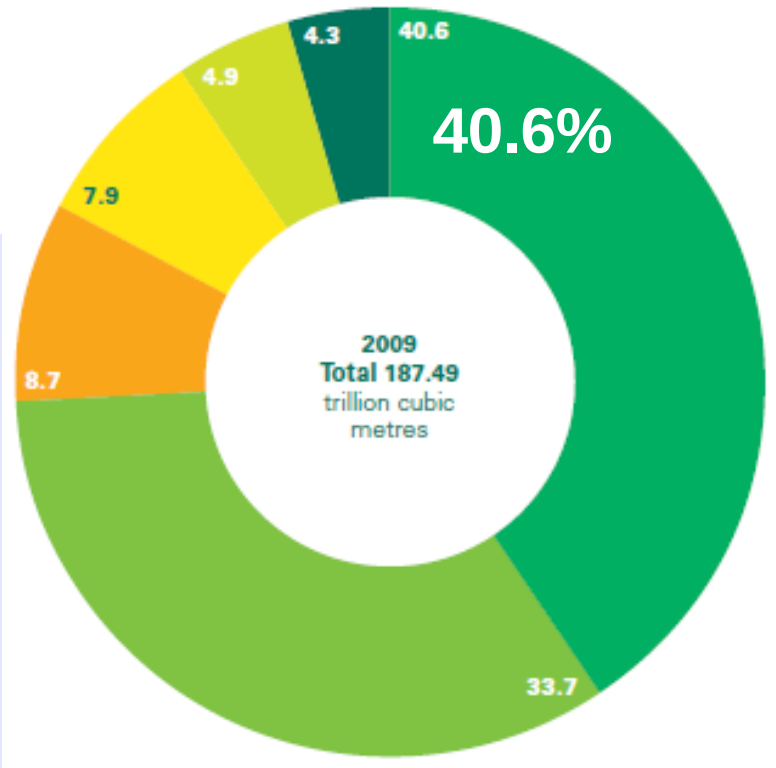
PROVEN OIL & GAS RESERVES 2009

Natural Gas Resources are More Diverse than Oil

Oil



Natural Gas



Source: BP Statistical Review of World Energy 2010

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NATURAL GAS VEHICLES ARE AVAILABLE TODAY

- Light duty cars and commercial vehicles
- Medium duty trucks
- Heavy duty trucks
- Buses
- Off road vehicles (fork lifts, etc.)
- Specialty vehicles (street sweepers, etc.)
- Boats, trains…….and planes!

OEM Statistics

(excluding China)

Europe

Worldwide

	Europe		Worldwide	
MODELS	Light Duty	31 (47)	Light Duty	49 (67)
	Heavy Duty	69	Heavy Duty	202 (215)
	Engines	15	Engines	44
MANUFACTURERS	Light Duty	10 (12)	Light Duty	16 (42)
	Heavy Duty	9	Heavy Duty	36 (37)
	Engines	3 (6)	Engines	13

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2009-2010

OEMs Available in Asia
A Growing Population

- Light Duty Vehicles
  - 27 OEMs
  - 72 models
- Heavy Duty Vehicles
  - 29 OEMs
  - 52 models

Growing numbers of bus OEMs in China

Asian NGV Communications, January 2010

RETROFIT SYSTEMS MANUFACTURERS

- Italy = 14 LDV
- Brazil = 3 LDV
- Argentina = 71(retrofitters or manuf.?)
- Netherlands = 2 LDV; 1 HDV
- US = 4 LDV; 1 HDV
- Canada = 2 LDV; 2 HDV
- UK = 2 HDV
- Australia = 4 LDV 1 HDV
- Bangladesh = 350 (only 192 *'authorized'*)
- Russia, Asia, = multiple hundreds (?)

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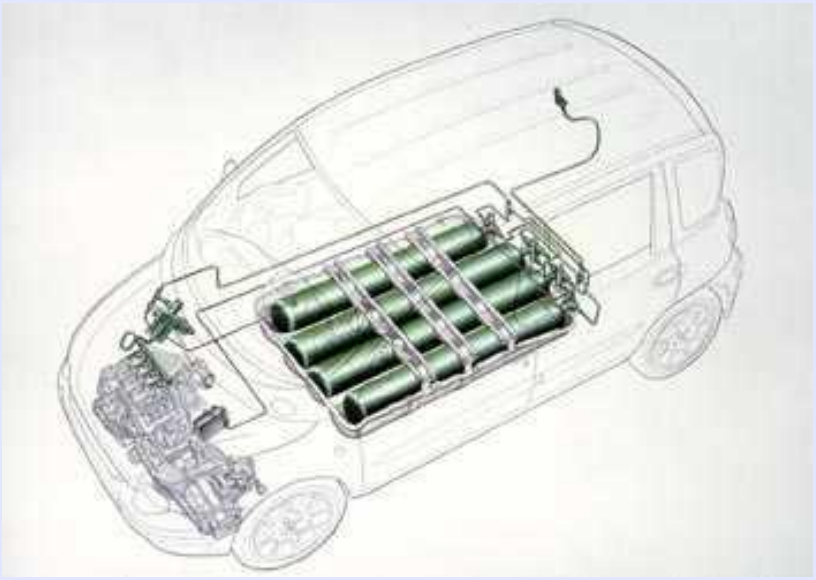
Modern Generation NGVs incorporate CNG cylinders in the chassis



Fiat Multipla Blupower; 1.6 L, 4 cylinders, 4 valve engine; cylinders in the chassis

EUROPEAN OEM NGVs 2011

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FIAT

Multipla

Grande Punto

Doblò

Panda

CITROËN

C3 Bi Energy M

C4 1.8 Bi Energy M

Berlingo

Fiat Qubo

MERCEDES

B 170 NGT

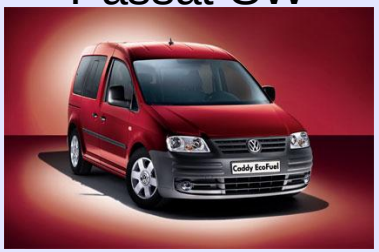
B 180 NGT

E 200 NGT Bi-Power EVO

Sprinter

VOLKSWAGEN

Passat SW



Caddy Life Ecofuel

Touran TSI Ecofuel

T5 2.0 Bi-fuel

EUROPEAN OEM NGVs 2011

*QVM= Qualified Vehicle Modifier

OPEL ZAFIRA

OPEL COMBO

VOLVO V-70 (QVM)*

IVECO

RENAULT KANGOO

Tata Indigo SW
(Indian made)

FIAT FIORINO NAT. POWER

FORD FOCUS (QVM*)

FORD CMAX (QVM)*

FORD TRANSIT

NATURAL GAS TRUCKS

Garbage Truck, Scania

Garbage Truck MAN

Delivery Truck, Mexico

NATURAL GAS BUSES

Iveco City Class CNG

Volvo B10L CNG

Mercedes Citaro NGT

City Transit Bus, Beijing

Off Road Vehicles

Audi race car Germany

Fork lift (Lift Truck)

Icecleaner, Germany

Natural gas Go Carts

MARINE APPLICATIONS

Viking Energy on LNG, Norway

Accolade II running on CNG, Australia

Natural Gas Converted Speedboat (Italy)

LNG car & passenger ferry , Norway

One of the 12 canal boats on natural gas in Amsterdam, the Netherlands

RAILWAY APPLICATIONS

CNG Locomotive in Minneapolis, USA

Dual-Fuel Train in Chile

Biogas Train, Svensk Biogas, Linkoping

Union Pacific, USA

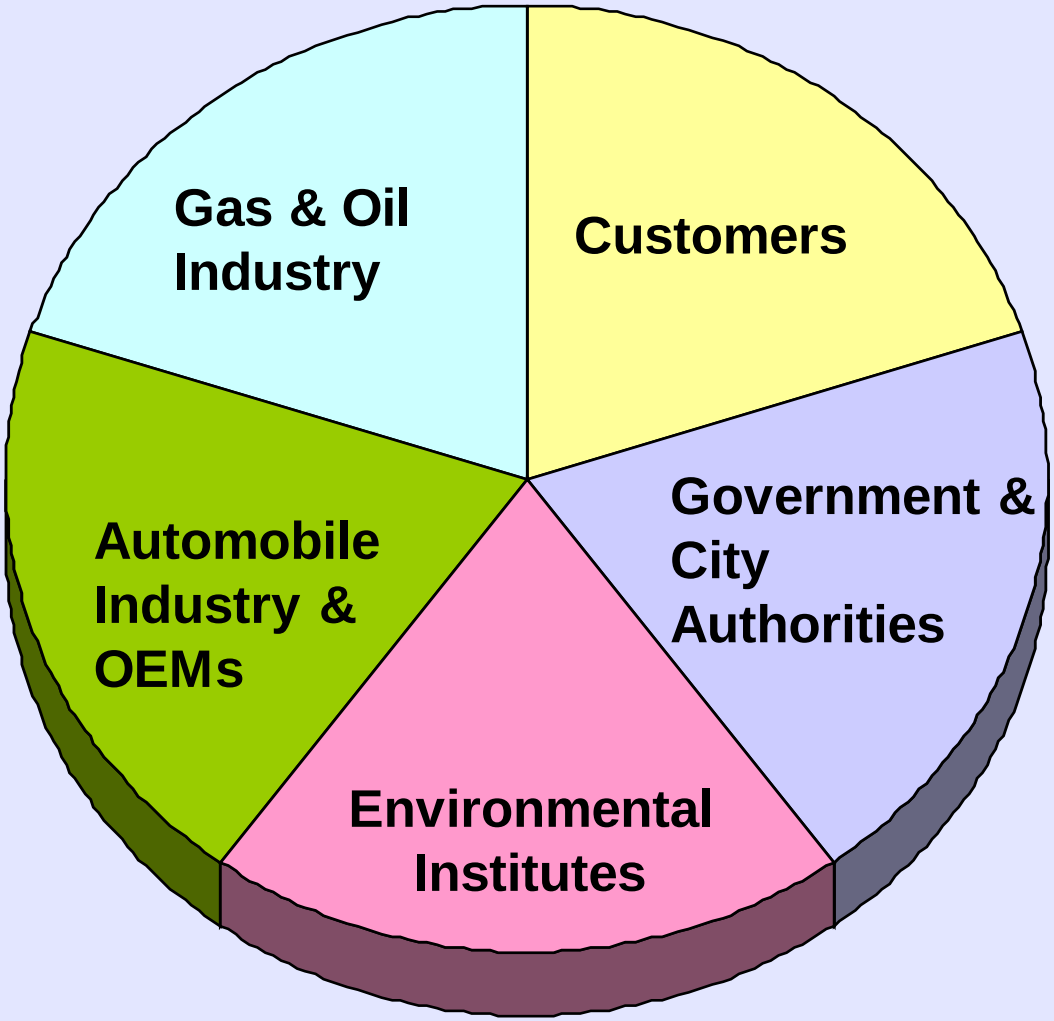
INDIA

BANGLADESH

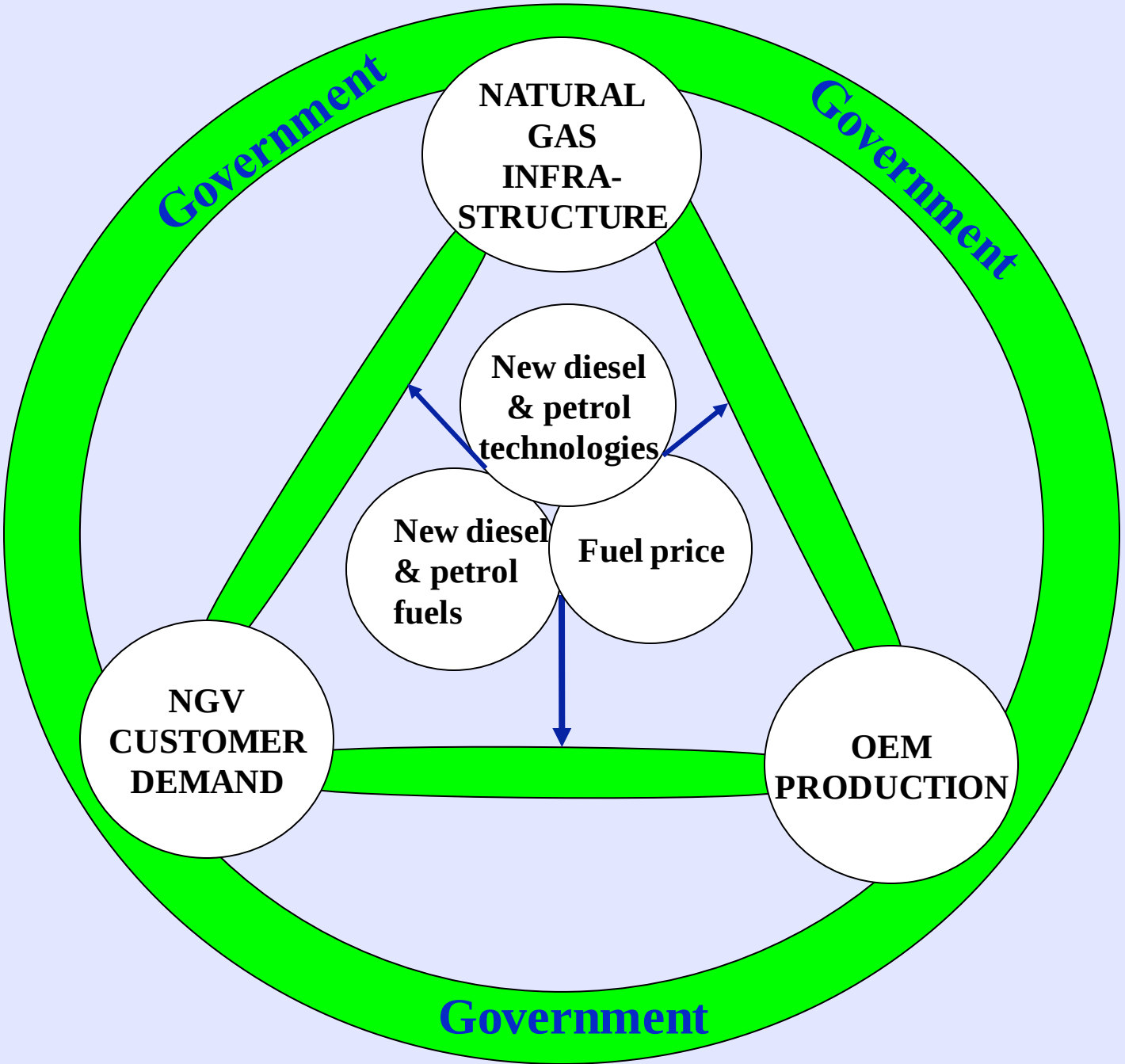
FACTORS REQUIRED FOR NGV SUCCESS

- Government commitment
- Energy industry support
  - Gas industry vs. Oil/Gas industry
- Availability of vehicles (*real*, & not *implied* support of manufacturers)
- Favorable economics
  - Cost differential between natural gas & petroleum
- Environmental policies driving lower emissions

THE CRITICAL "NGV" STAKEHOLDERS (EACH ONE HAS A ROLE TO PLAY)



Balance of NGV Commercialization



THE INVOLVEMENT OF GOVERNMENT IS *ESSENTIAL** (Strategies Supported by Specific Actions!)

- Create Incentives (financial & others)
- Enforce Mandates (but *with* incentives)
- Develop Standards
- Fund Research & Development
- Leadership by Example
- PR & Communications

*** What's good for one alternative fuel is good for them all!**

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Government Support

- **Government incentives remain a key to NGV development**
- **A wide variety of government incentives have appeared worldwide**
  - **Fiscal: cash rebates; exemption from congestion charges; tax benefits (road, income, property fuel; etc.)**
  - **Free parking; lanes at airports/train stations**
- **Some countries mandate NGVs**
  - **Venezuela: 40,000 NGVs**
  - **Iran: As many that can be converted**
  - **India: Diesel buses, 8 regions and more to expand**

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Regional Views: Strengths, Weaknesses, Opportunities & Challenges




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Europe

Government Approaches

- National approaches vary but German example of a well-organized coalition of stakeholders is a valuable model of NGV development.
- Sweden = 'municipality' motivated approach.

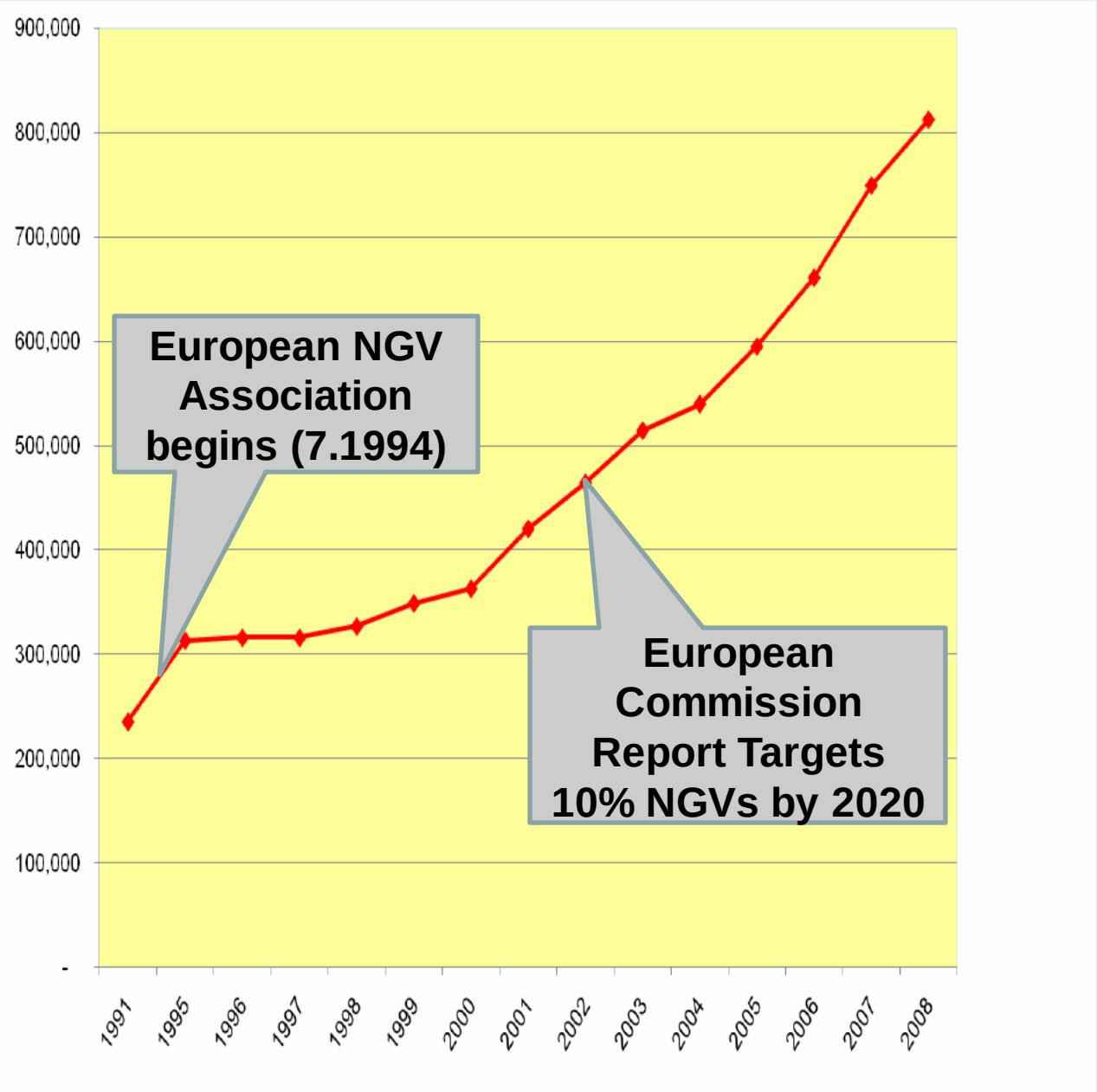
Fuelling Infrastructure

- Ratio between fuelling stations and vehicles in Europe not economically sustainable at current levels
- North-south 'corridor' exists: Italy-Germany-Sweden.
- If fuelling network continues to be developed then the OEM development will keep the NGV market alive.

Overall NGV Development

- Growth expected to be helped by tighter emissions regulations, and energy security concerns.
- An overall European approach to NGV development is required but remains lacking.

European NGV Growth 1991-2008



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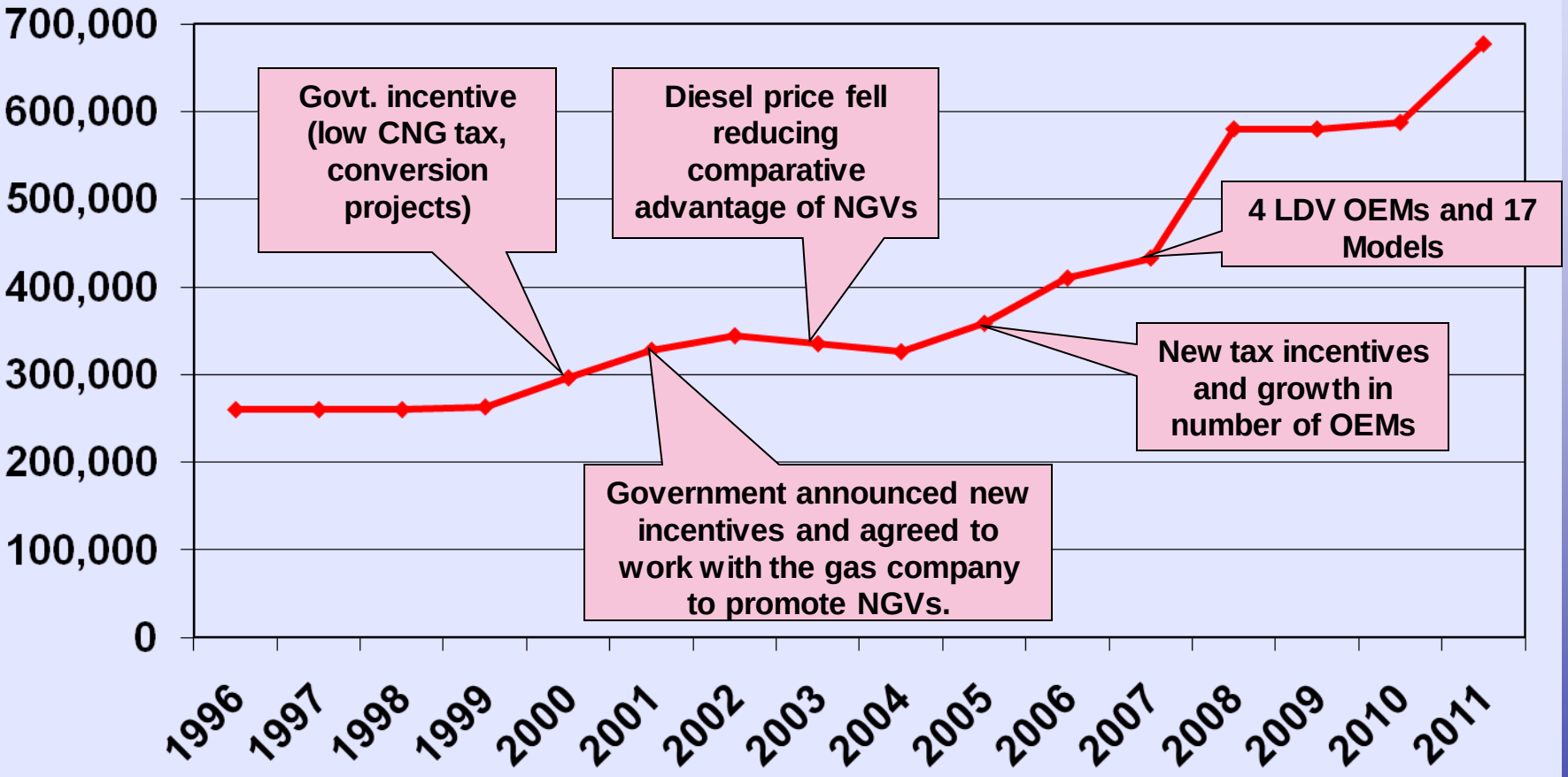
ITALY HAS STRONG NGV GROWTH HISTORY



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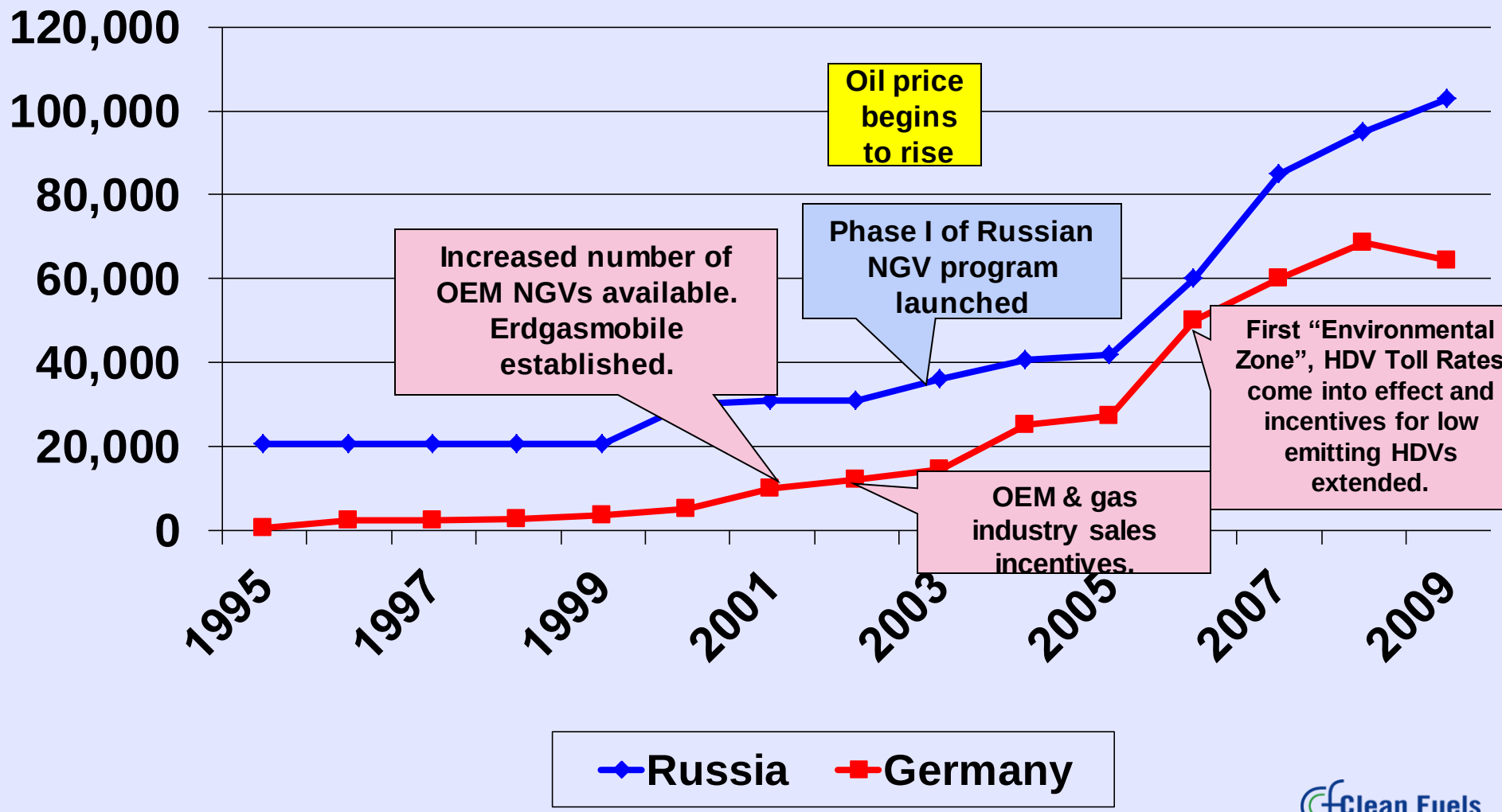
NGV Growth
Russia & Germany



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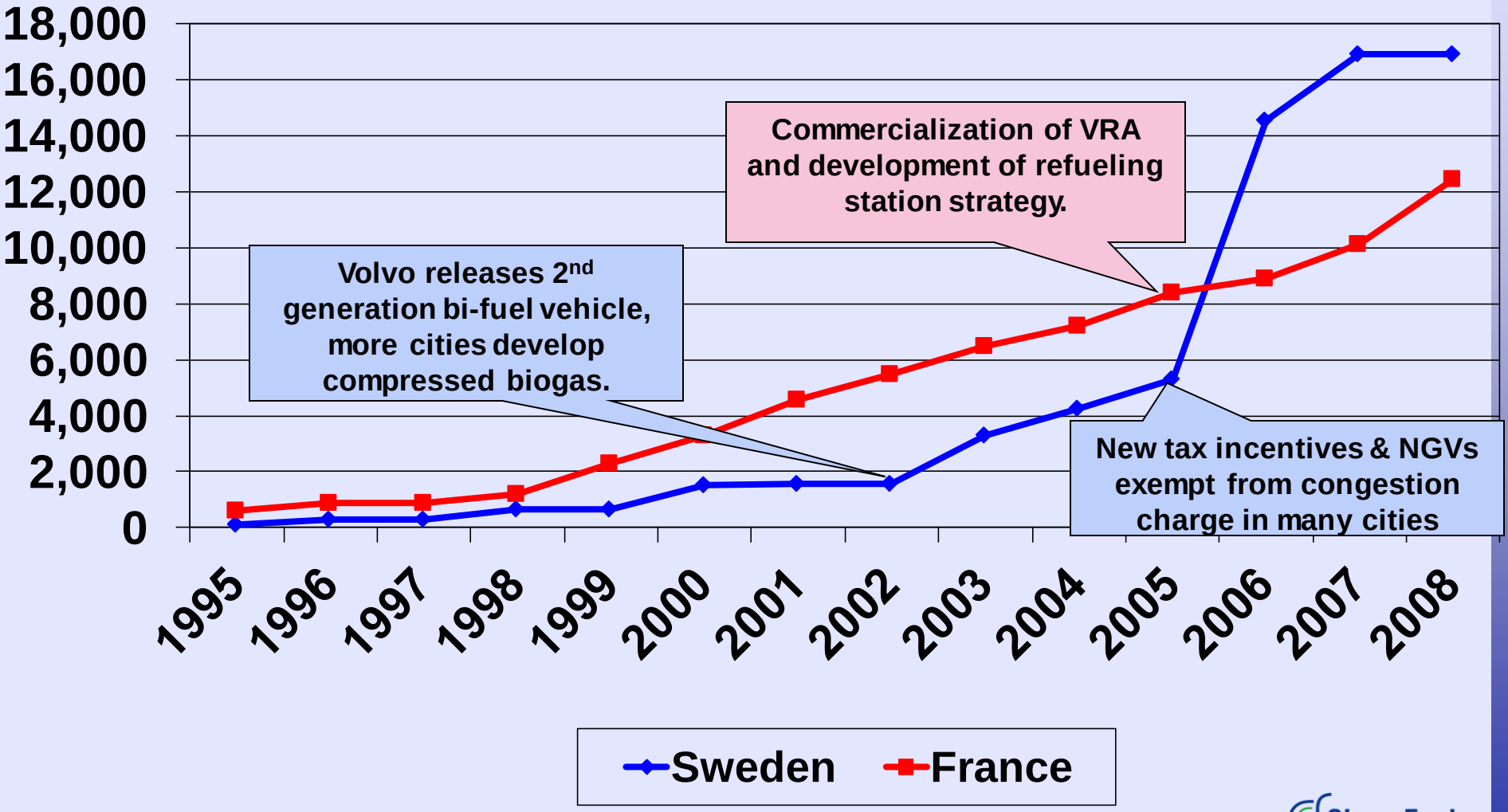
NGV Growth
Sweden & France



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North America

Overall NGV Development

- Despite early growth, by the year 2000 the demand for NGVs was insufficient and NGVs suffer due to other AFVs competition and loss of OEM NGVs.

Incentives

- Past incentives (US & Canada) have been too short for major market impact although there are new and potentially powerful legislative initiatives (2009).

Vehicle Availability

- HDVs remain the strongest market for NGVs with growing potential for LNG.
- Only Honda produces OEM NGV (limited to 1000 units per year). As of 2011 this OEMs *may* start returning.
- Domestic NGV & equipment suppliers in the USA are sustained mainly due to their international business.

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South America

Overall NGV Development

- NGVs have grown rapidly due to favorable CNG-petrol price differential, availability of retrofits and the development of the fuelling network.
- South America expected to continue to see strong *regional* growth with more countries joining the program, strengthening the role of domestic and foreign NGV businesses.

Gas Supply

- Generally favorable gas supplies impeded by irregular growth of pipelines, political instability, and program to nationalize foreign investments.

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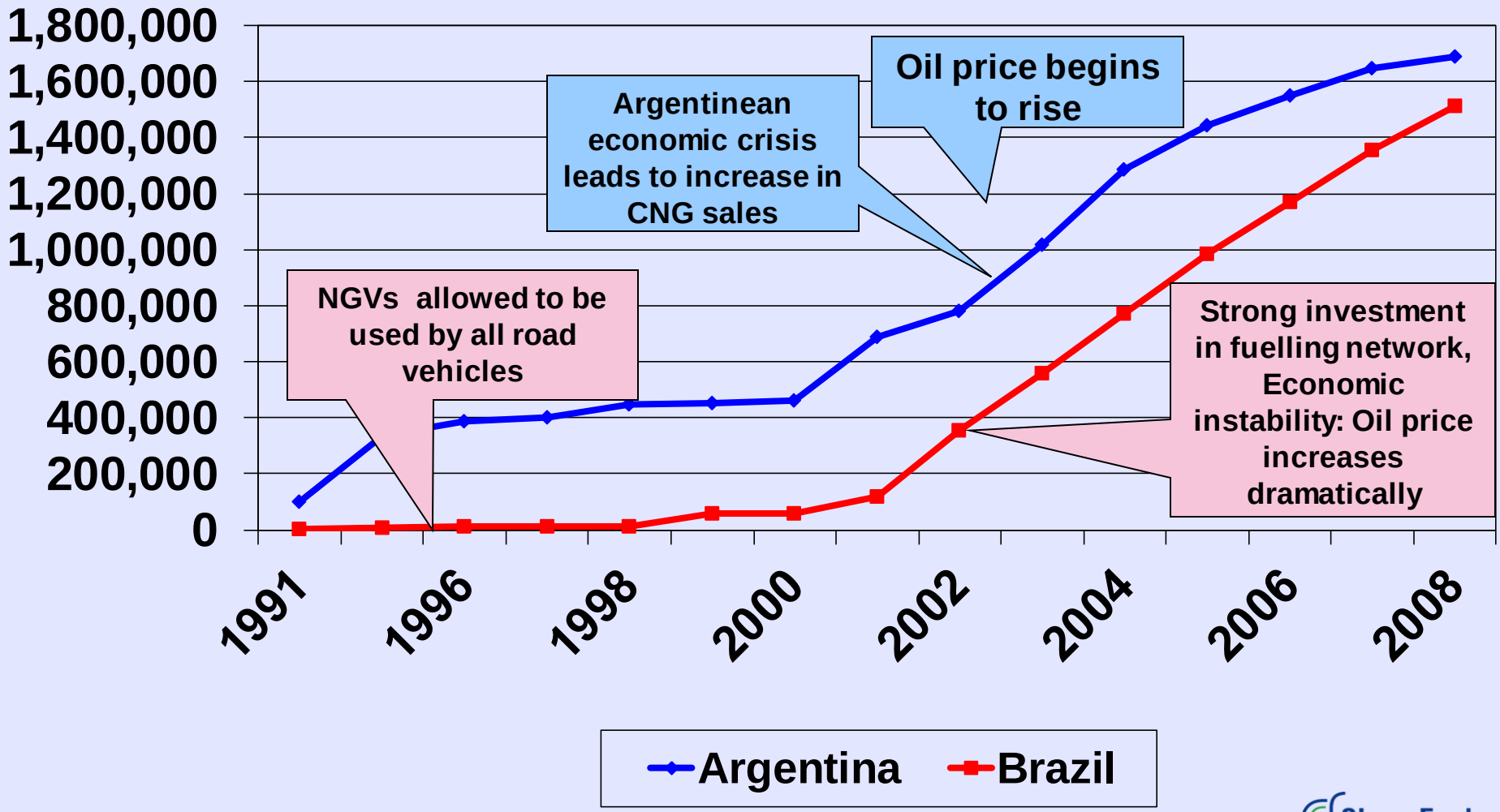
NGV Growth Argentina &Brazil



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Asia

Overall NGV Development

- Consistent incentives need to remain in place to motivate long term market growth.
- Public transport (buses & three wheel vehicles) will help continue to drive NGV expansion in many countries.
- With rapid market growth, safety will remain a concern. NGV image could be seriously damaged unless safety and training are higher priorities.

Gas Supply

- Natural gas distribution grid expansion is needed, although many countries are addressing gas supply and natural gas transportation issues.
- Increasing availability and use of LNG in many Asian countries strengthens NGV potential and diversity.

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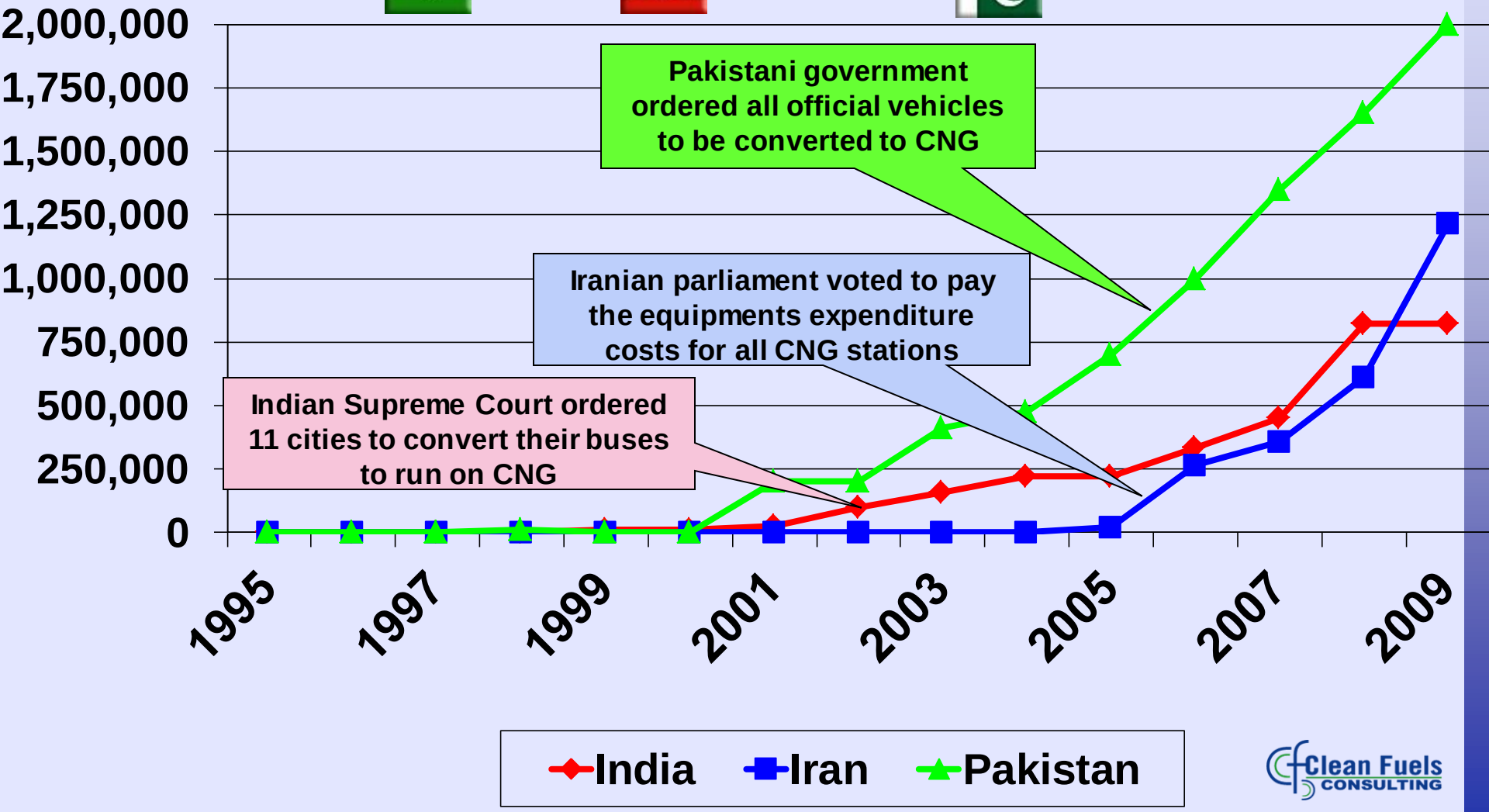
NGV Growth

India, Iran & Pakistan



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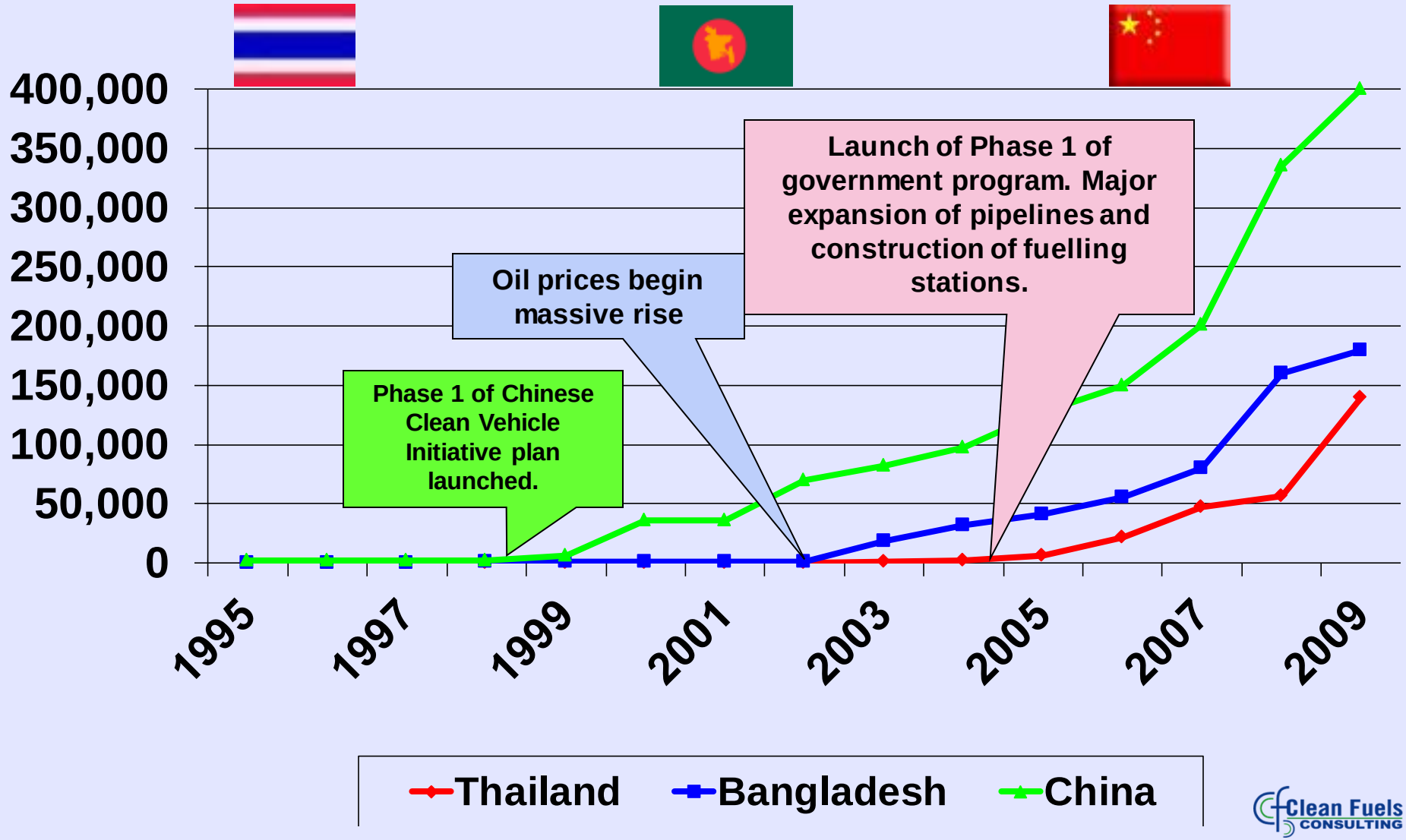
NGV Growth

Thailand, Bangladesh & China



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Developing Markets for NGVs

Biomethane

&

Liquefied Natural Gas (LNG)

NATURAL GAS IS A VERY DIVERSE FUEL WITH VARIOUS LONG TERM OPTIONS

LNG Will Capture More Markets

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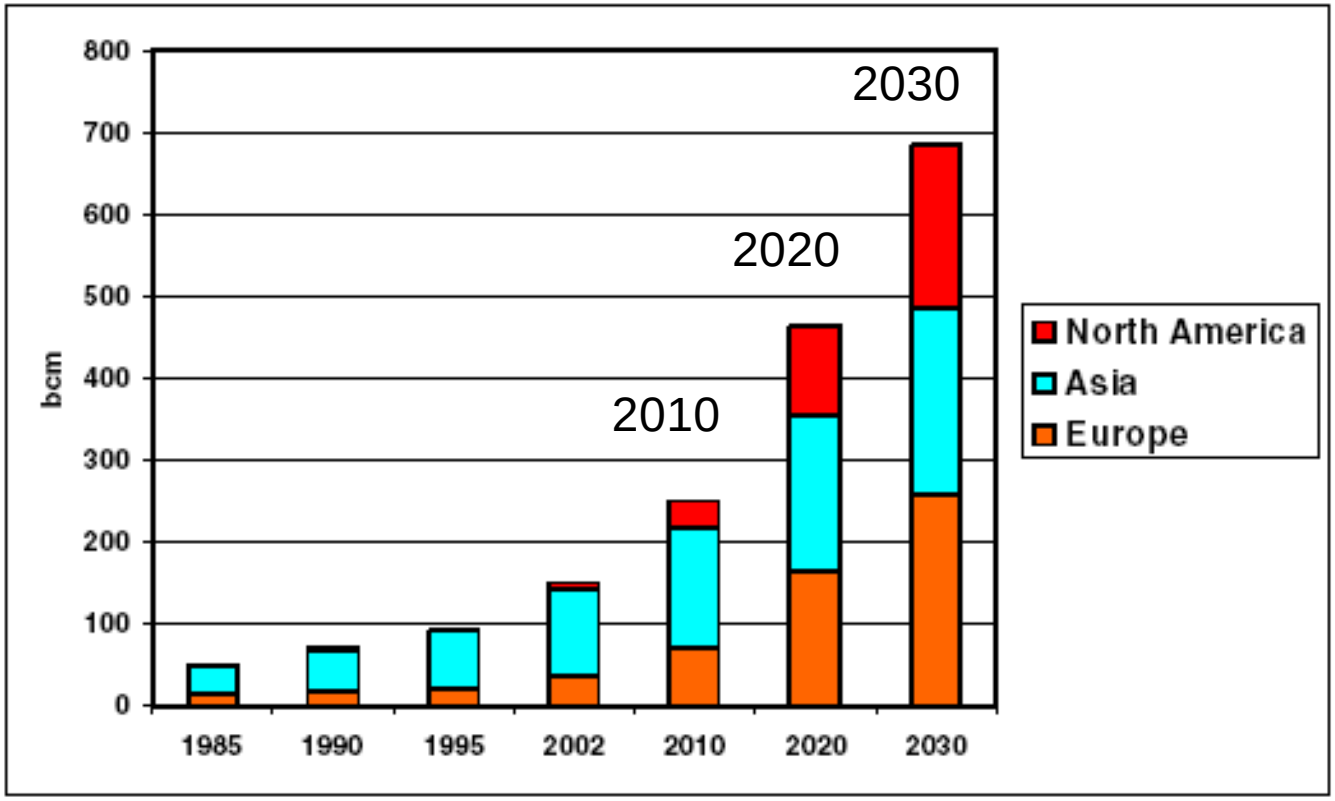
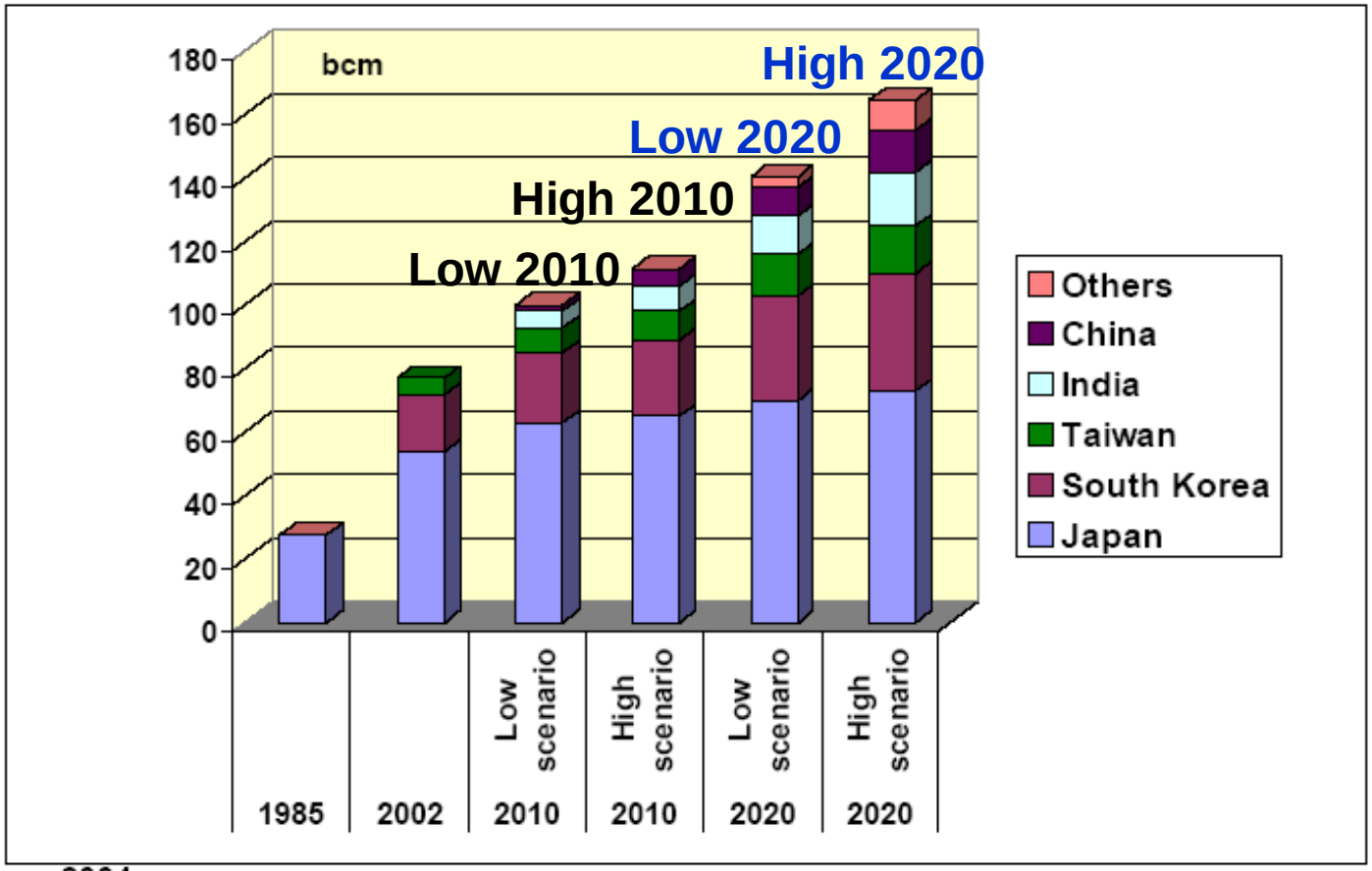
A Tremendous Growth for LNG Trade



Source: World Energy Investment 2004

INTERNATIONAL ENERGY AGENCY AGENCE INTERNATIONALE DE L'ENERGIE

Future Asian LNG Imports



Cedigaz, 2004

LNG VEHICLES

LNG fuelling: Los Angeles

Cummins Westport ISL-G (LNG) Engine

Kenworth T800 Westport ISX HPDI

Photos courtesy Clean Energy

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LNG-Fuelled Vehicles

Biomethane:
NGVs are Part of a Renewable Energy Strategy

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RENEWABLE BIOMETHANE

Multifaceted Solution to Multifaceted Problems

- Feedstock from various waste products
  - **Agricultural (animal, plant & wood: not food supply!)**
  - **Sewage from water purification**
  - **Urban waste**
- Biogas feedstock conversion efficiencies 40-70%
- Injected into natural gas grid or supplied locally
- Can reduce <100% CO2 emissions compared to gasoline car on a well-to-wheel basis
- Potential to replace 20% of petroleum in European transport sector by 2030
- **Production infrastructure required!!**

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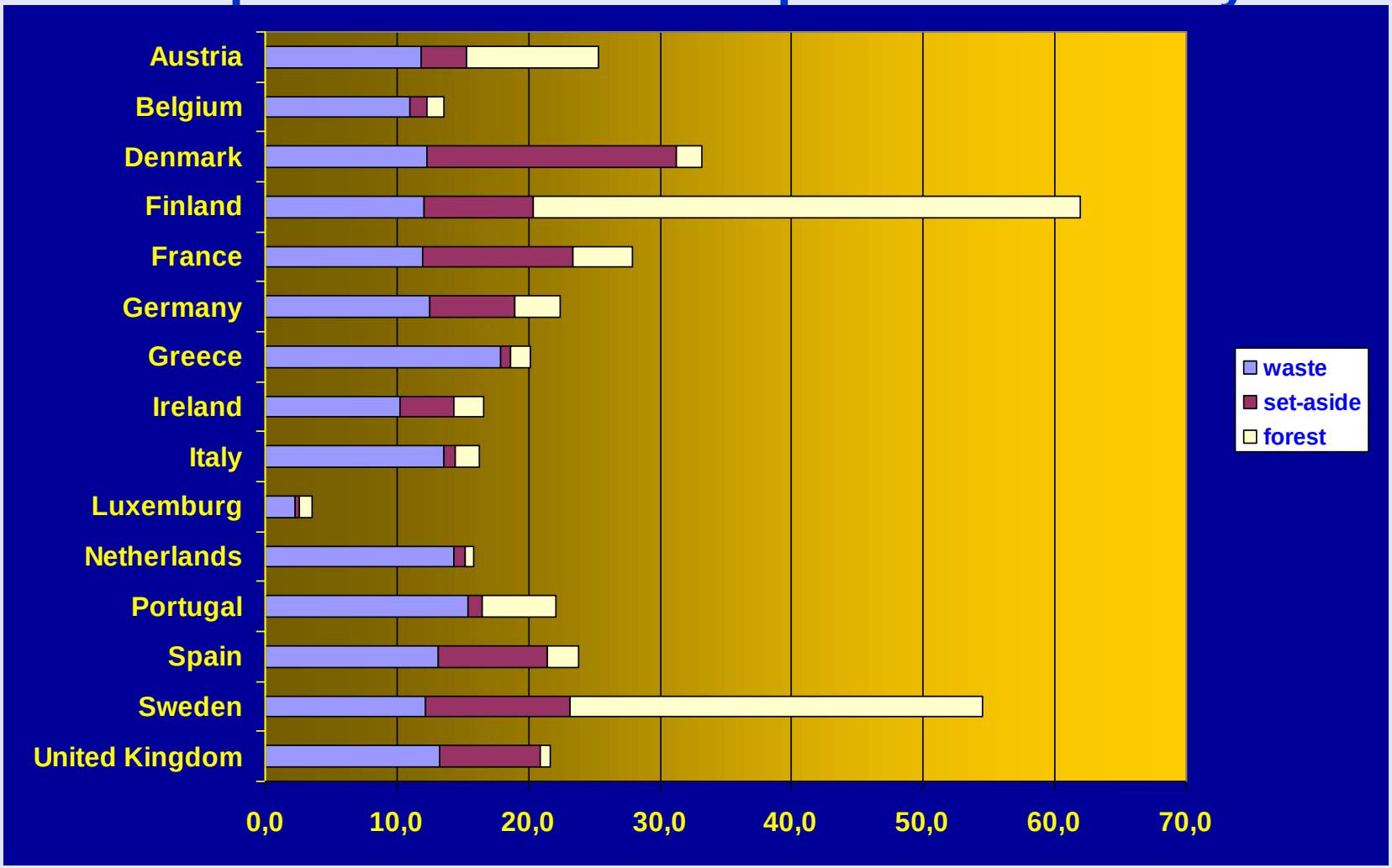
EUROPEAN BIOMETHANE POTENTIAL

(% of all vehicle fuels)

Could replace 20-30% of transport sector fuel by 2030!



•The numbers presented are reasonable estimates of averages for indicated regions, based upon knowledge available at the time the slides were prepared. Choice of crops, soil conditions, climate conditions, water supply, labor cost, technology choices etc means that results will vary. Conventional organic waste, use of currently set-aside land, assumed 8 % of annual forest growth. (Target 2010, P.Boisen,2003)

RENEWABLE BIOGAS-to-BIOMETHANE

The Environmentally 'Closed Loop'

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CHALLENGES FOR NGVs

- **High first cost of vehicles**
  - ***– Target high fuel consuming customers***

- **High cost of fuelling stations**

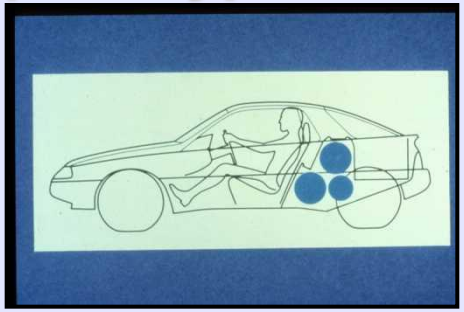
CHALLENGES con't

- Gaseous fuel properties present technical challenges
  - *Energy density affects vehicle range*
  - *Heavier storage tanks required*
  - *Gas is harder to ignite in engines*
- Fuel composition varies

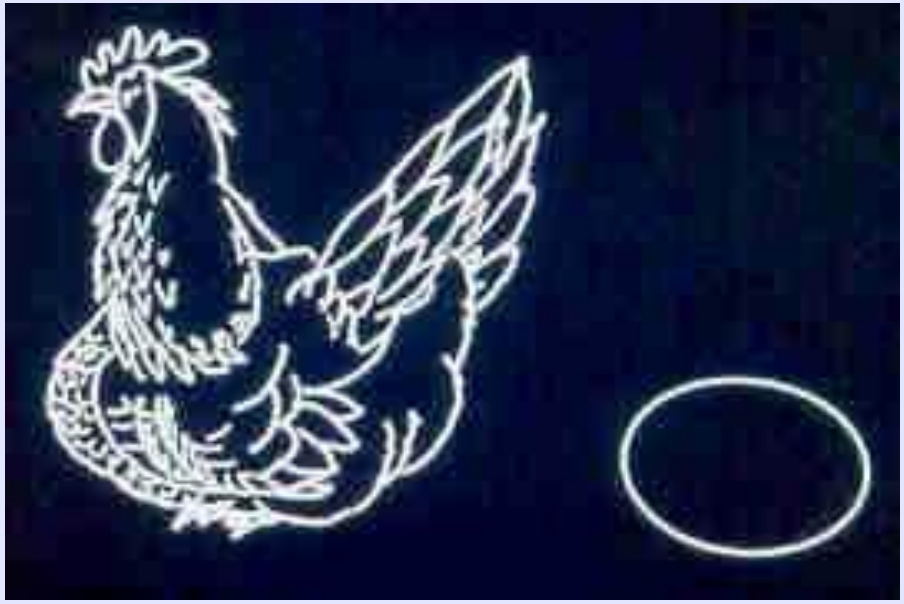
CHALLENGES con't

- NGVs lack *'sex appeal'* of electric, hydrogen & fuel cell vehicles
- Public generally not knowledgeable about NGVs or their benefits *(more knowledge-building to consumers is needed)*
- Liquid fuels are the foundation of the OEM and oil industries. Changing the *status quo* is a complex process but, ultimately, must be driven by market demand.

First Ford NGV prototype 1983



WHICH COMES FIRST, THE CHICKEN OR THE EGG? (Vehicles or Fuelling Stations?)



THE ANSWER IS:

They both have to come at (roughly) the same time.

THERE ARE NO FUEL PANACEAS

- Every fuel has its benefits and its challenges
  - Cost
  - Environmental quality & impacts
  - Energy availability & security
  - Compatible vehicle technologies
- The critical challenge is to find the right balance and mix of fuels in the marketplace
- Petroleum-based vehicle technologies improve but need better quality and more expensive fuels
- Creates new opportunities for alternatives but…
- Status-quo liquids will be around for a long time

IN CONCLUSION

- **Economical NGV technology** is available today, both OEM and retrofit and for a full range of on-road and off-road vehicles.
- **Environmental advantages** of NGVs are clear
- **Natural gas supplies** – fossil and renewable – are abundant
- **NGV awareness must improve** (clean fuel & energy security).
- ***Despite the challenges, NGVs are a fuel and technology of choice***

Clean Cities Transportation

Workshop for Almaty

NGVs in their Global Context: Opportunities, Challenges, & Strategies

Almaty, Kazakhstan

30-31 March 2011

Dr. Jeffrey M. Seisler, CEO

Clean Fuels CONSULTING