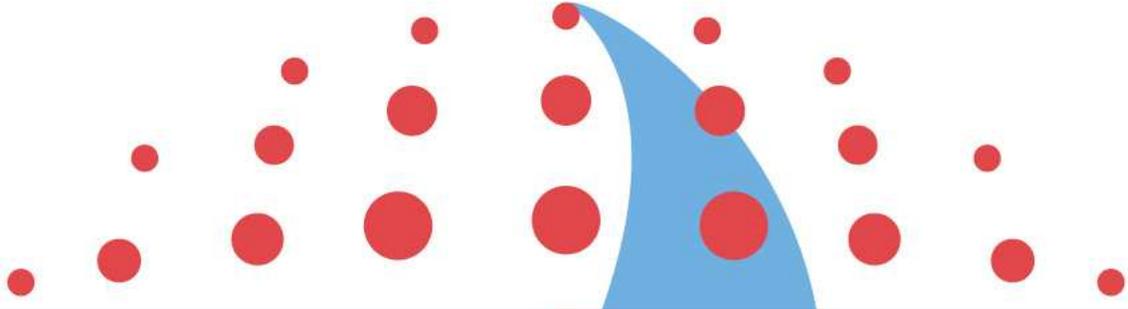


2006
IGU
H



**Progress and Future of
Clean Transportation Fuels :
CNG, LCNG, LNG, Biogas, H2**



**George H.B. Verberg
President International Gas Union
ANGVA 2005, Kuala Lumpur, July 27**





INTERNATIONAL GAS UNION

Covers >95 % of World Gas Sales
'Spokesman' of the Gas Industry



www.IGU.org

 Non Members

 Membership from 66 countries and 18 Associated Members



IGU's Objectives



- **Gas as the Fuel of Choice preceding a Sustainable Energy System (Bridging Fuel)**
- **Promotion of the Gas Industry as a Responsible Corporate Citizen**
- **Promotion of Technology, Industry and Customer Focus**



Early Gas Distribution in China, to Serve the Customer!

There is a Keen Local Interest
in Promoting Gas Usage

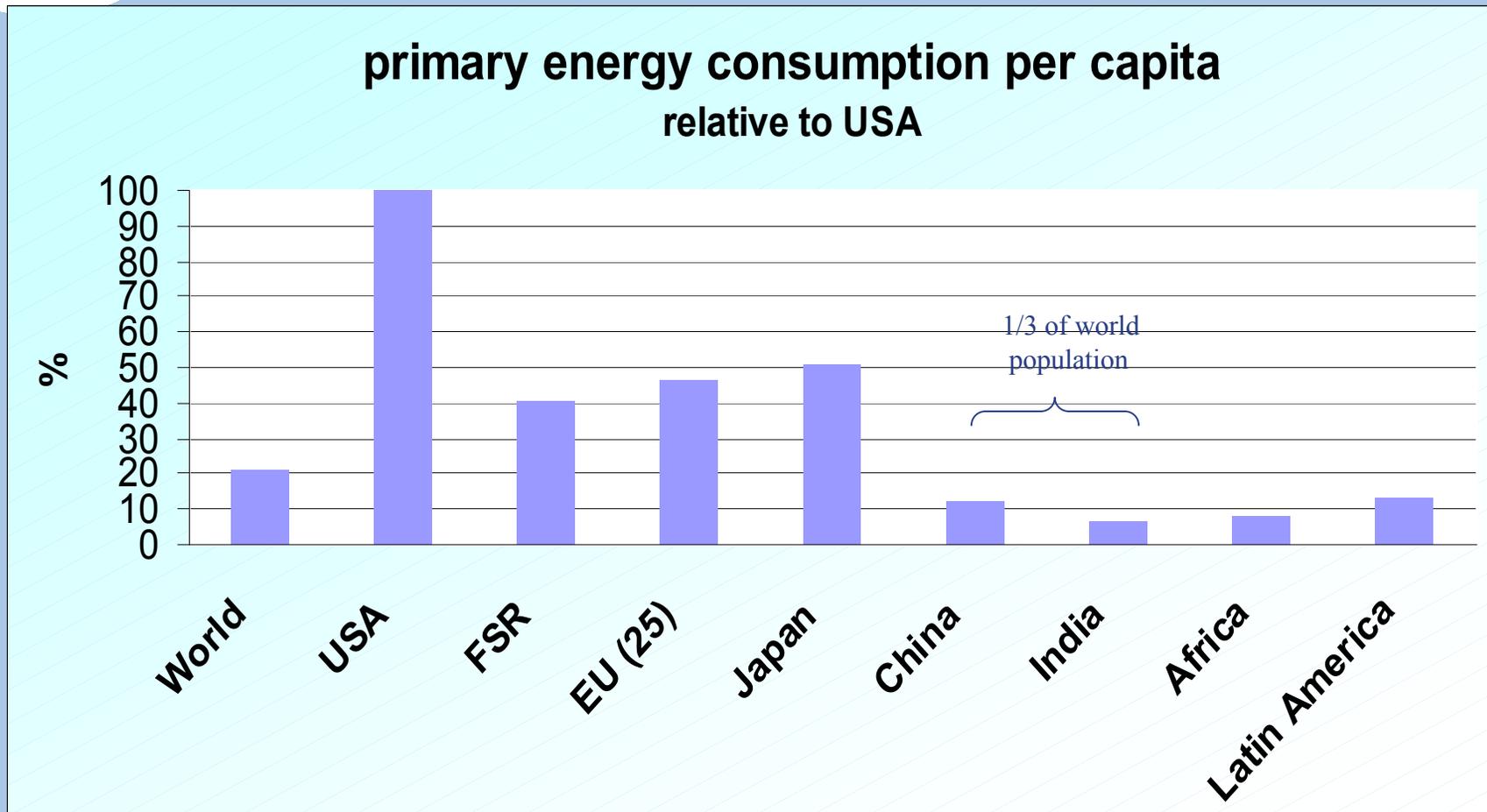


2

JONES
DAY



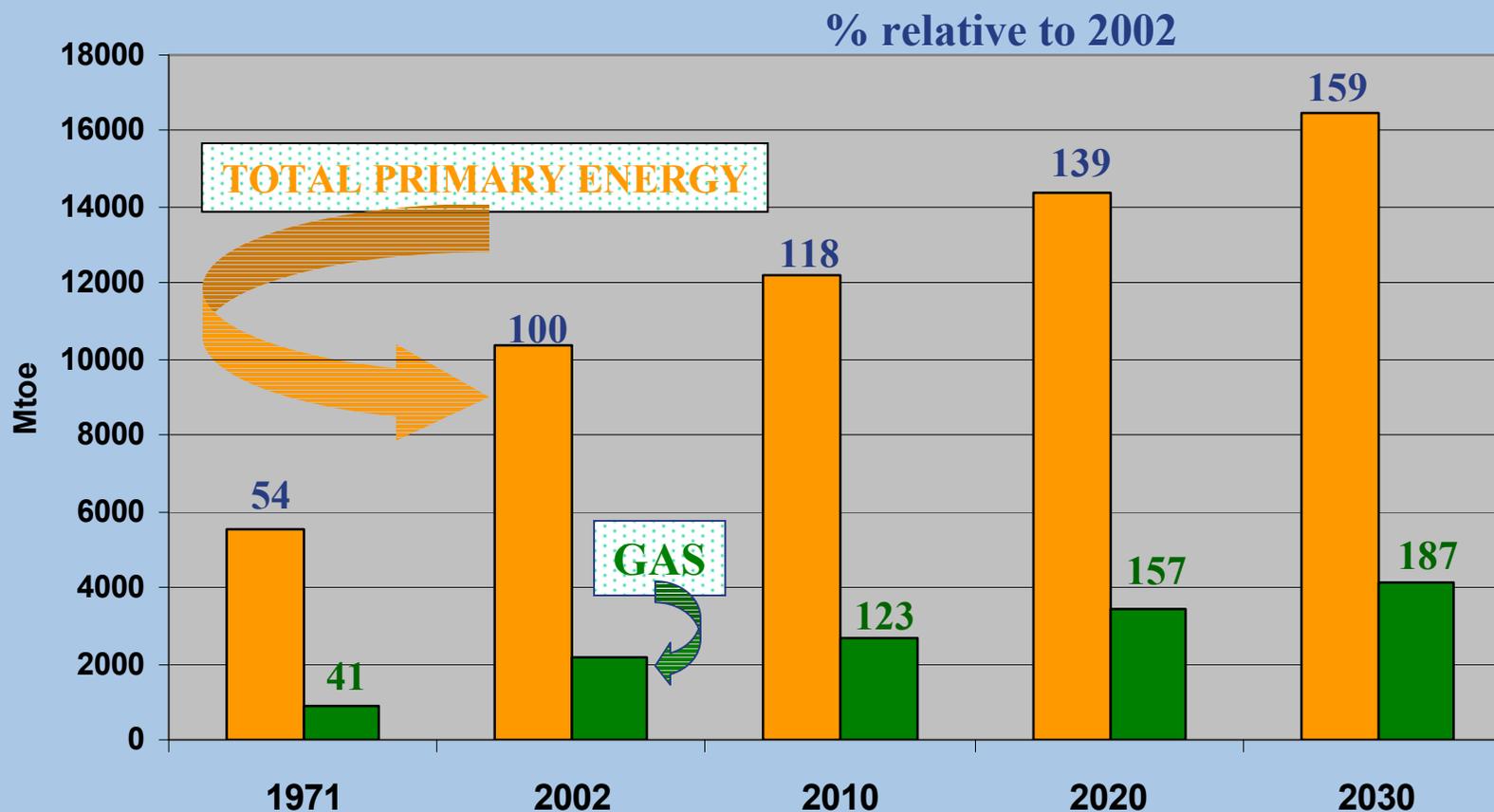
Energy Consumption in Perspective



IEA data year 2002

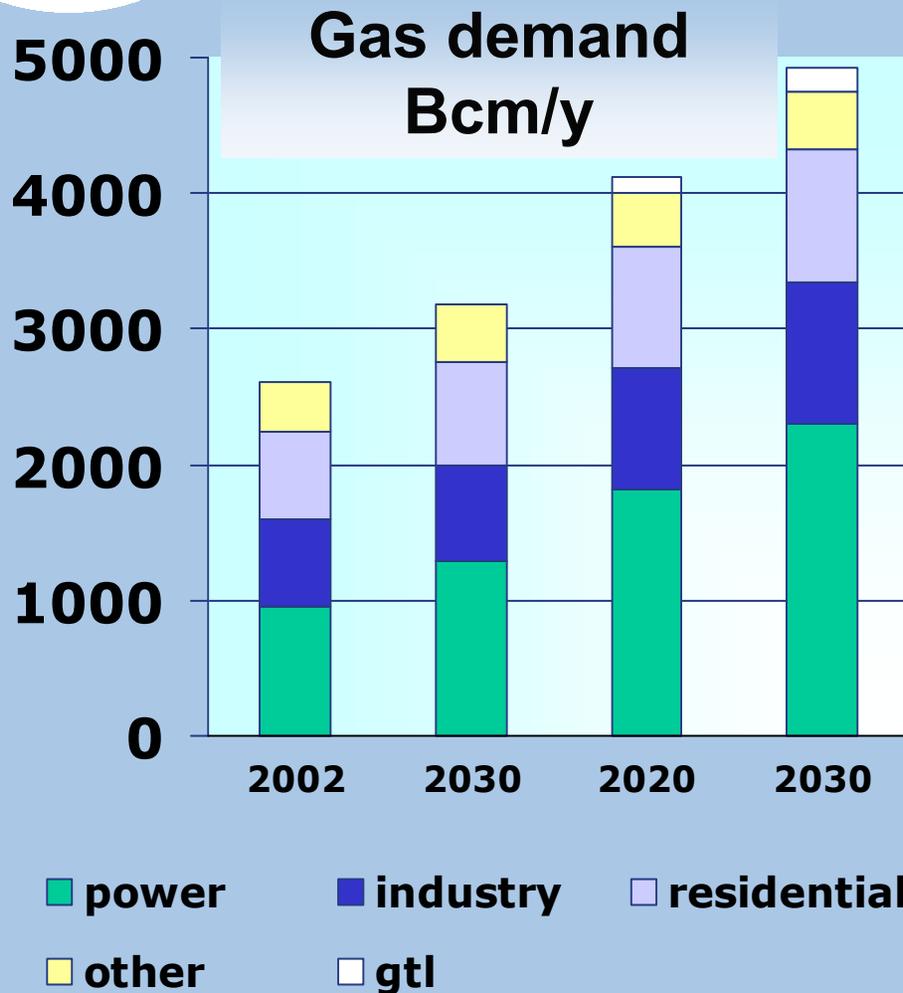


Global Energy Demand Forecast IEA WEO 2004





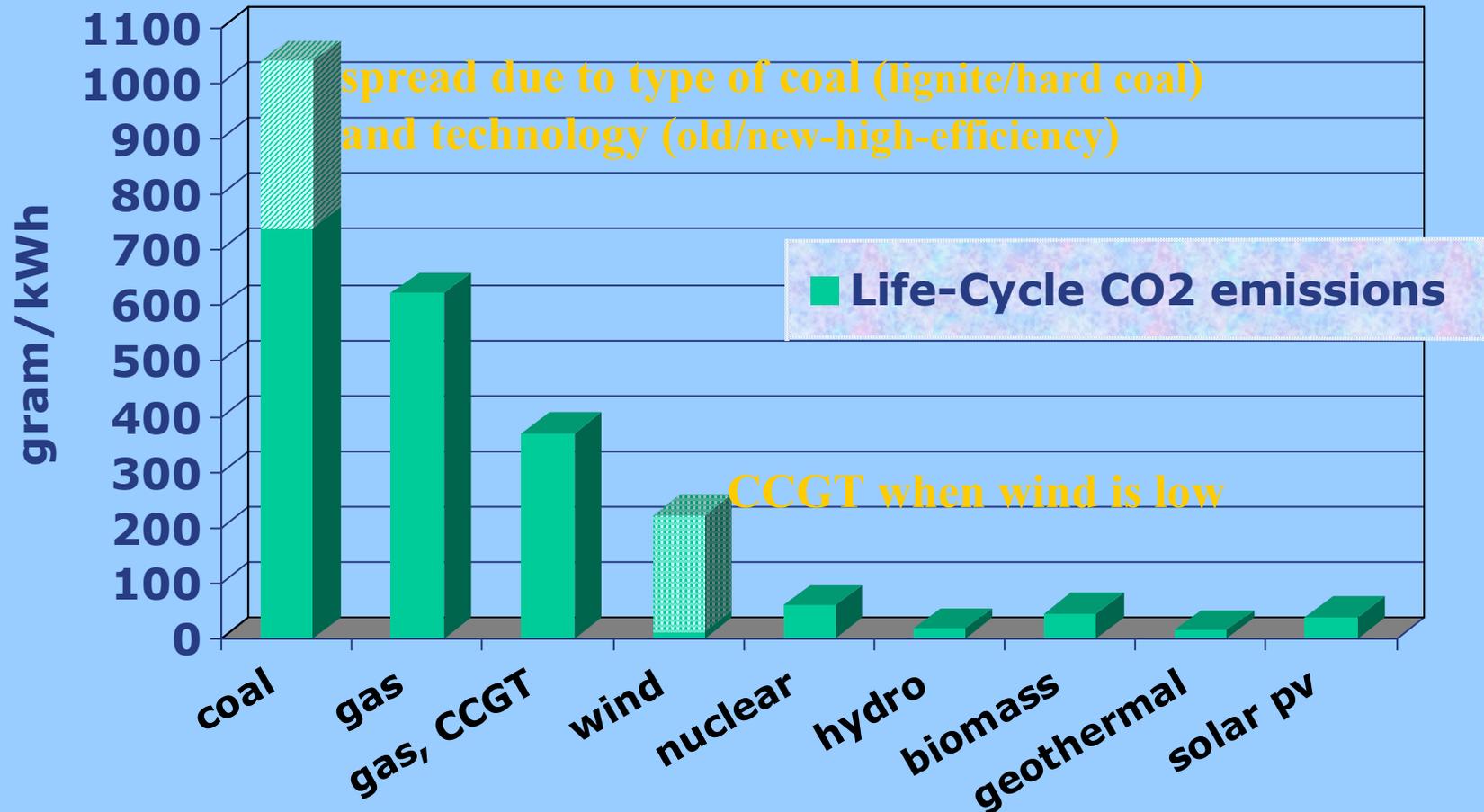
Gas Demand Forecast per Market Sector



- Power is expected to lead the increase in gas demand: from 36% in 2002 to 47% share of gasmarket in 2030
- High gasprice could shift generators' choice for new powerplants to (clean)coal, nuclear



CO₂ Emission from Power Plants

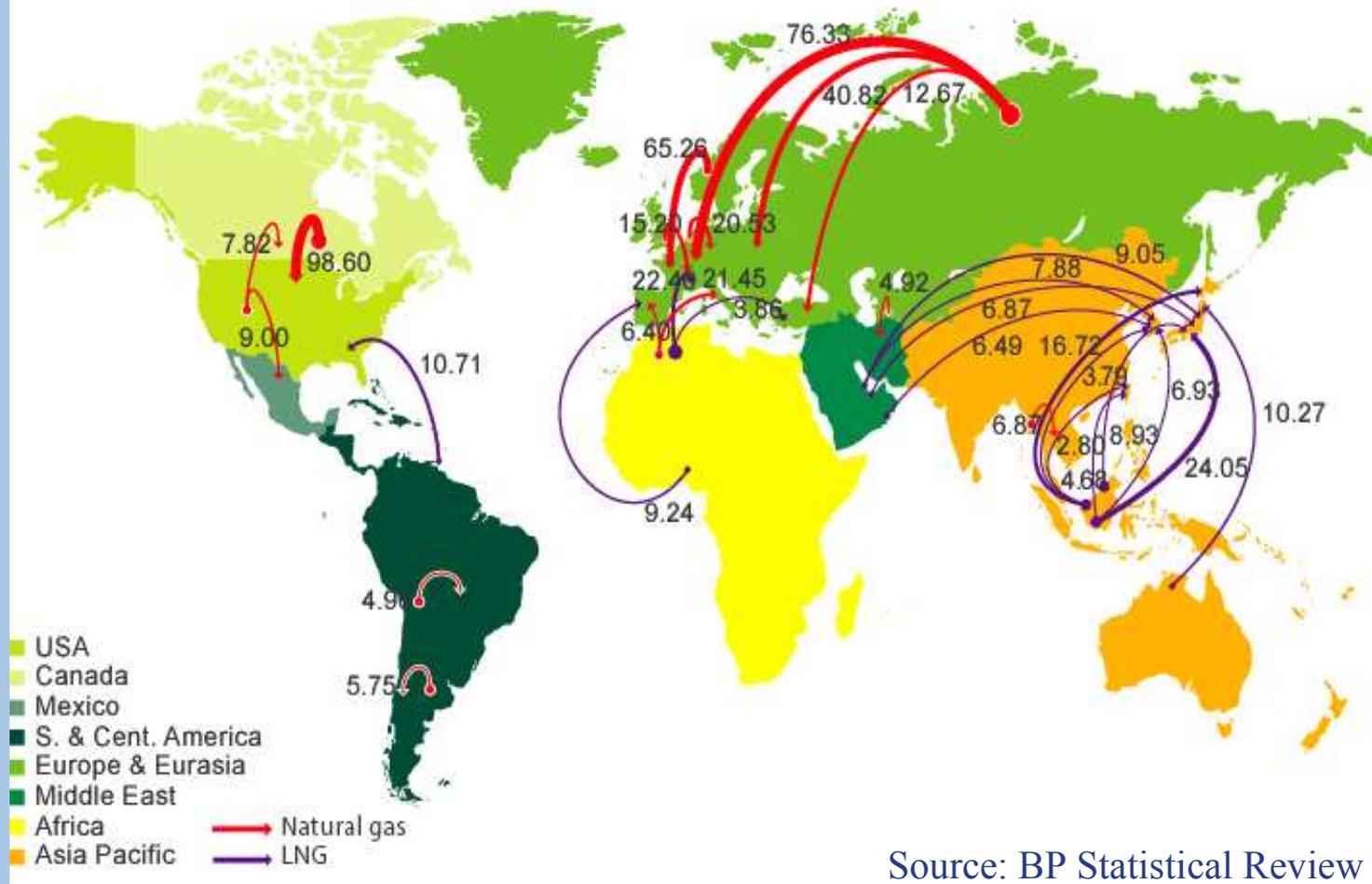


Sources: life-cycle assessment of electricity generation systems and applications for climate change policy analysis, Meier, 2002, published on website Nuclear Energy Institute; own data; IEA



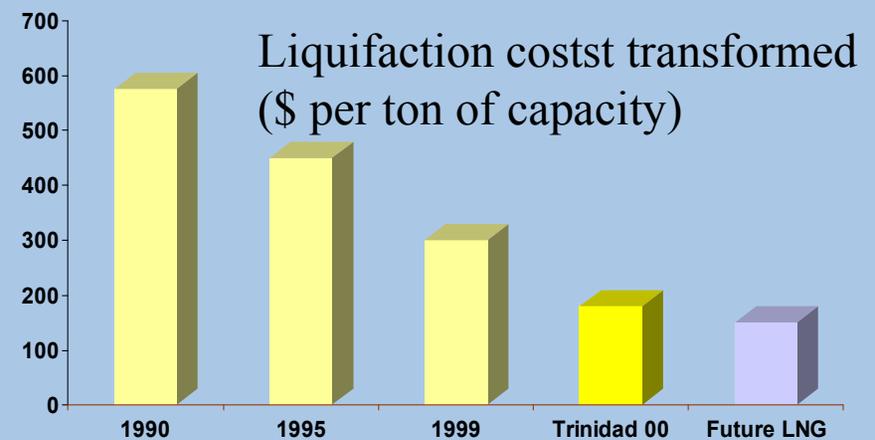
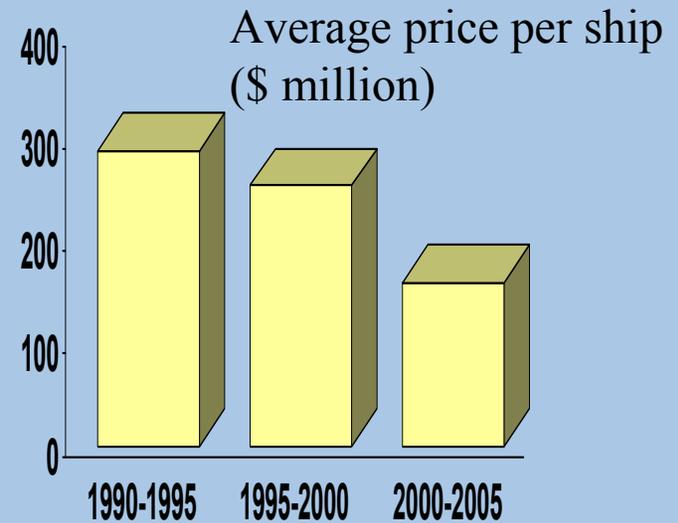
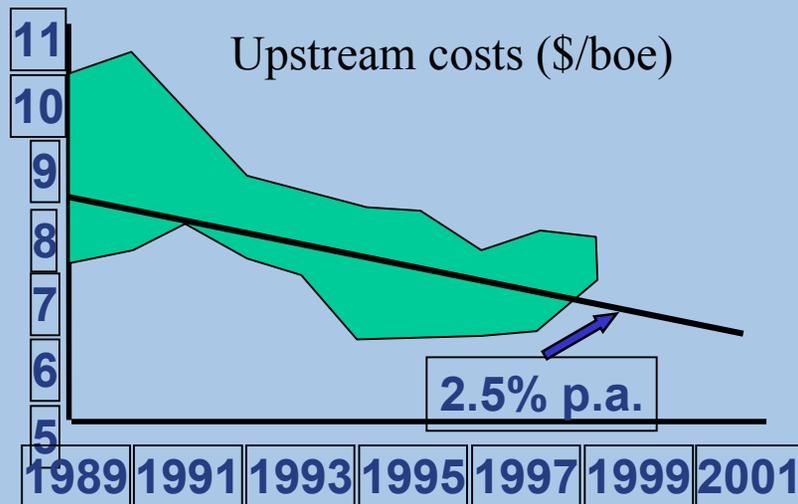
Major Natural Gas Trade Movements

Trade flows worldwide (billion cubic metres)





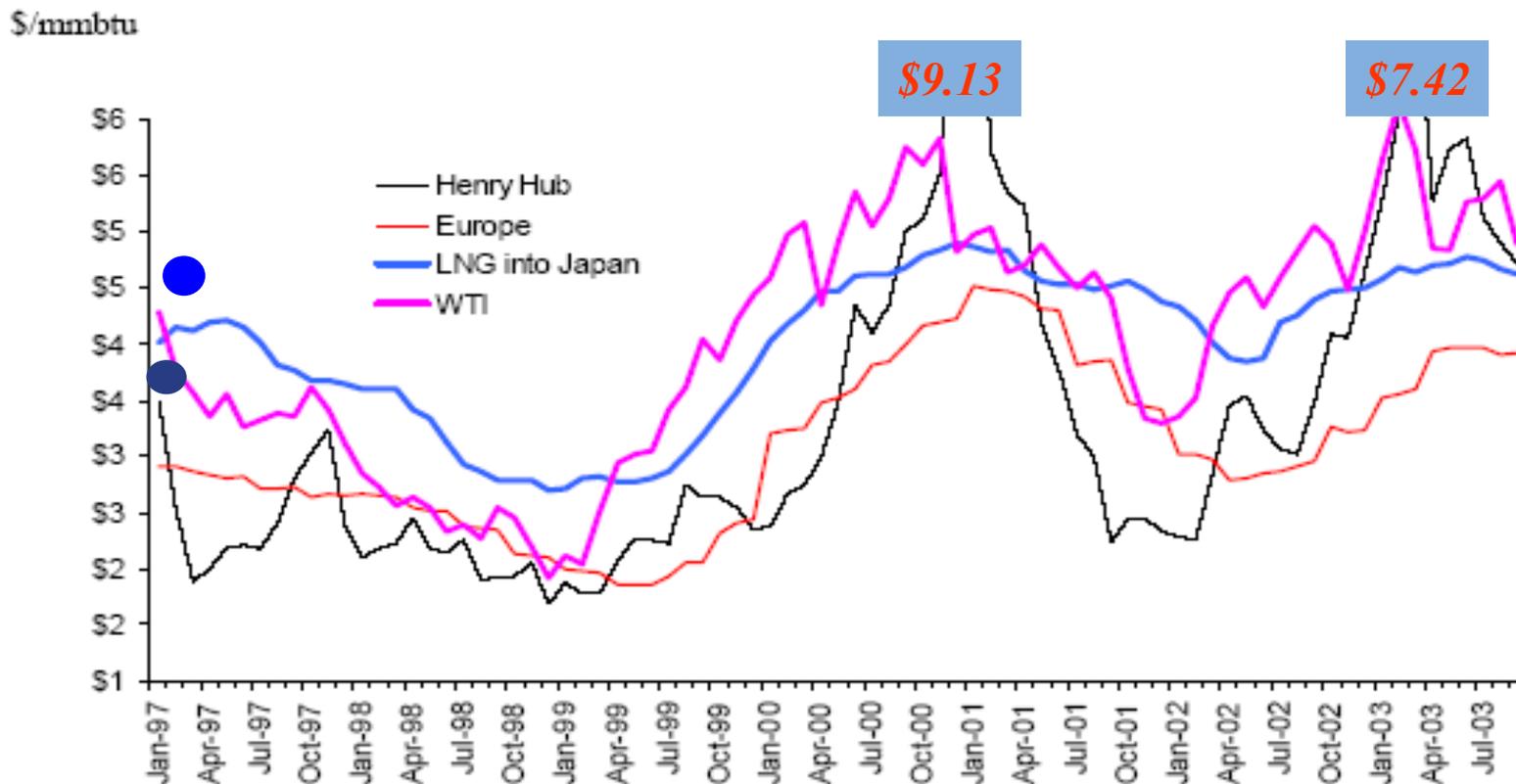
Costs in the LNG Chain



From a presentation by BP
(february 2003)



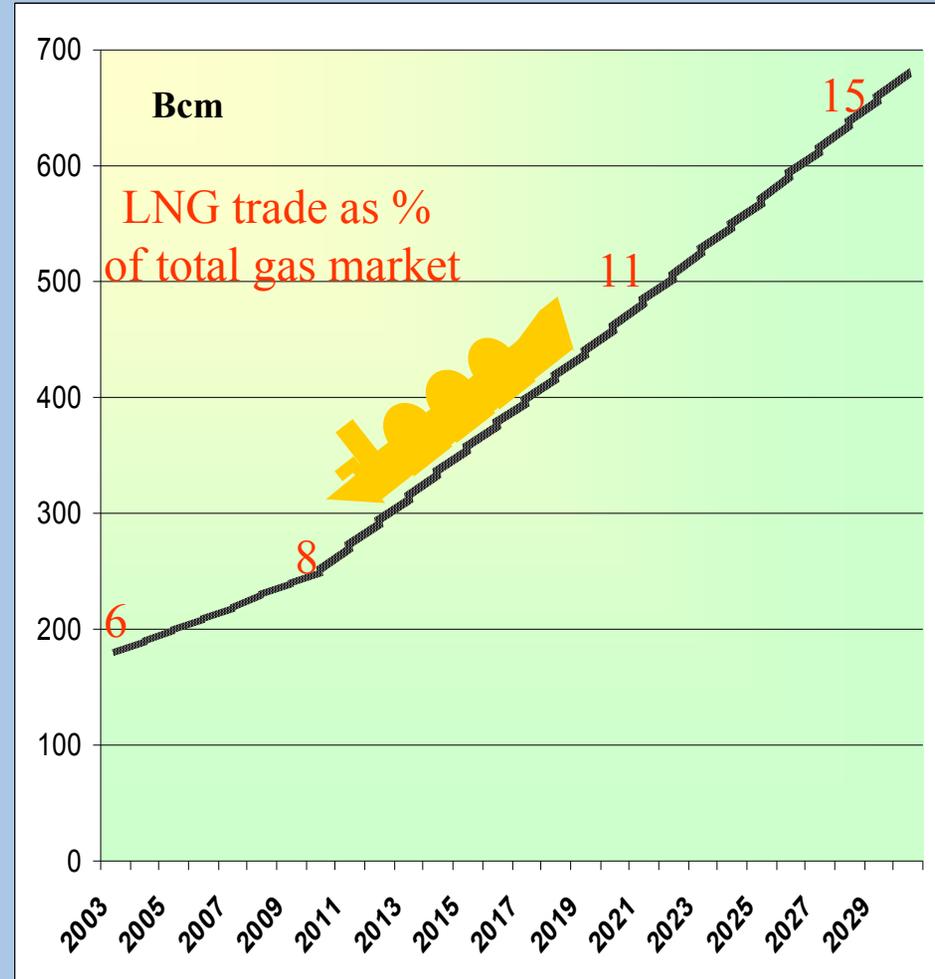
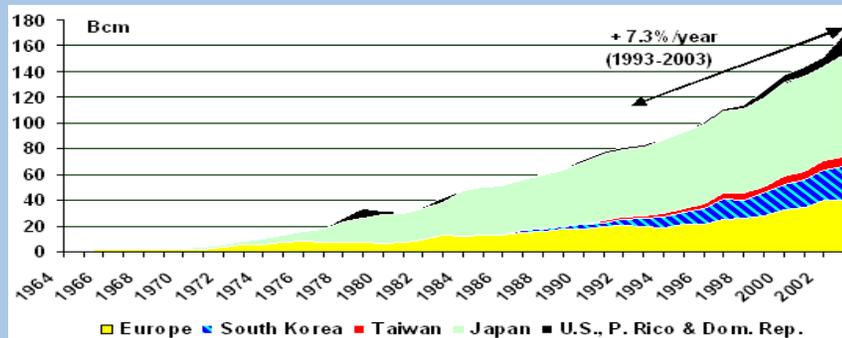
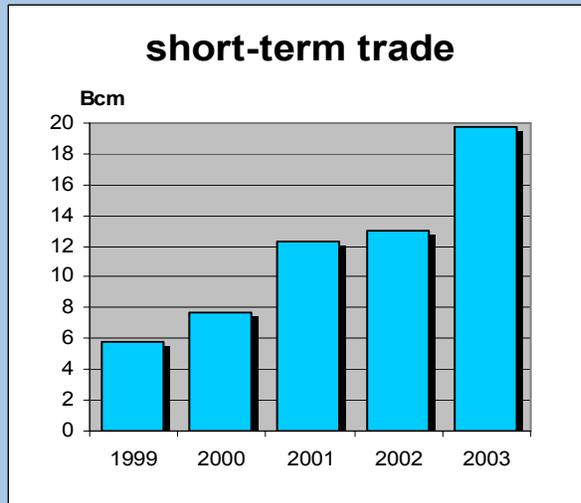
The price gap ; Henry Hub vs. LNG into Japan



Source : *The future relationship between LNG pricing In the Asia-Pacific and the Atlantic-Mediterranean, PFC Energy*



LNG Trade History and Perspectives





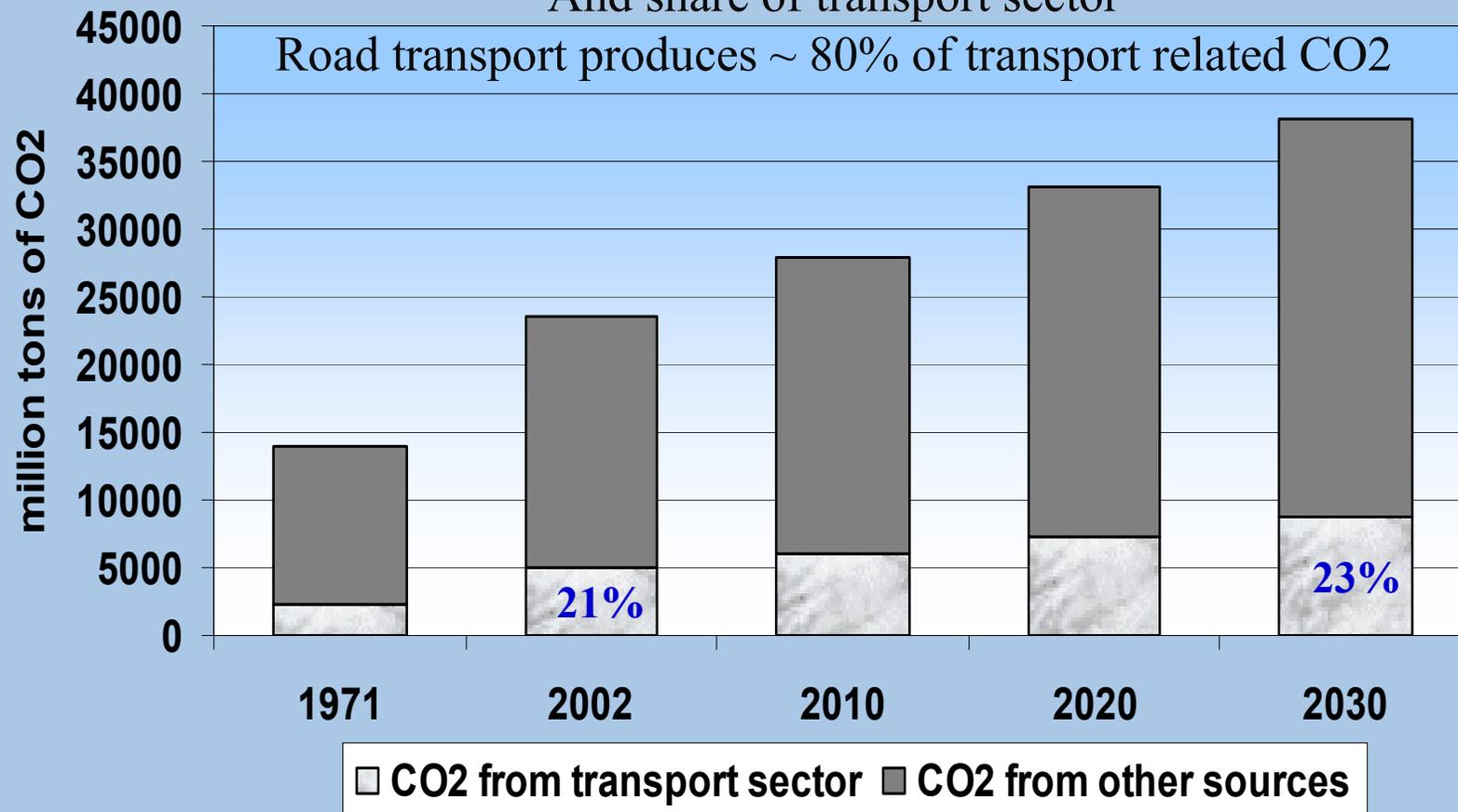
International LNG Trade: Connecting Markets





Transport Sector's Emission of CO₂

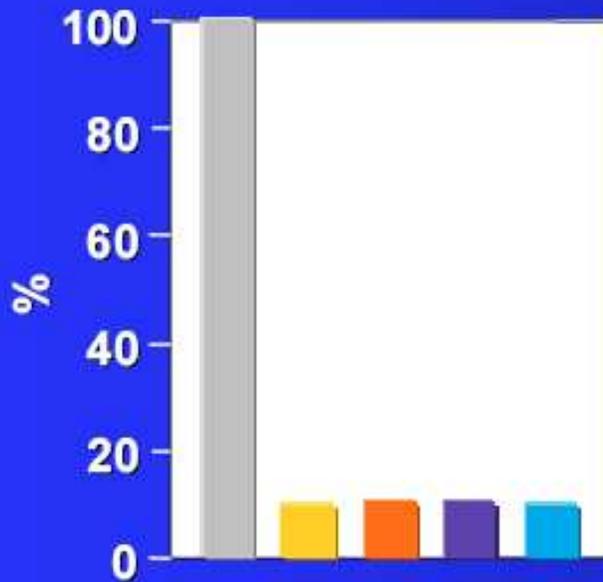
World CO₂ emissions from fuel combustion
And share of transport sector



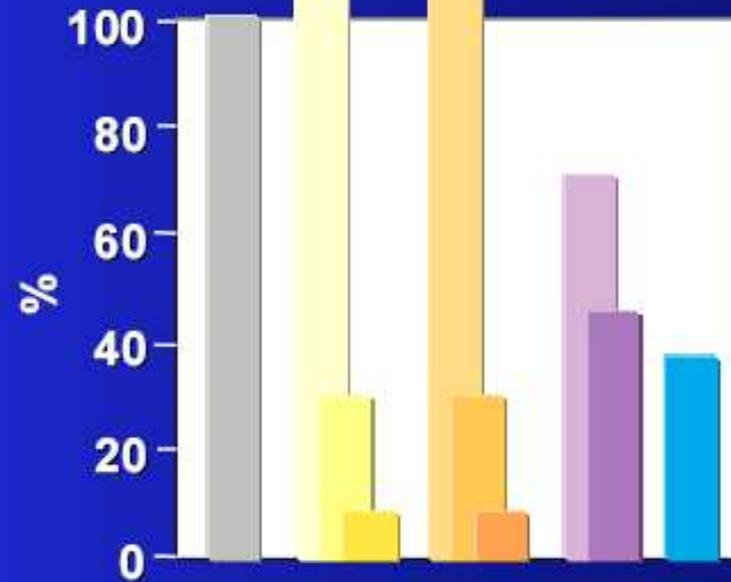


Engine Emissions

PM



NO_x



- Diesel, EURO II engine
- CNG
 uncontrolled combustion
 lean burn
 stoichiometric (TWC)
- LPG
 uncontrolled combustion
 lean burn
 stoichiometric (TWC)
- DME
 mechanical FIE
 electr. controlled FIE + Oxicat
- MeOH engine, electronic control + Oxicat



HEALTH EFFECTS OF PARTICLES

- **Coarse particles**
 - diameter $>1 \mu\text{m}$, not very harmful
- **Accumulation mode particles**
 - diameter 30-50 nm.... $1 \mu\text{m}$
 - mostly products of incomplete fuel combustion, soot
 - carry suspected genotoxic constituents of the emission (higher molecular weight PAC compounds)
- **Nanoparticles**
 - diameter $<30-50 \text{ nm}$, mostly condensed volatiles
 - typically more than 90 % of total particle number (advanced engines)
 - penetrate into the lowest parts of the respiratory tract
 - they may dissolve into the body fluids and the blood circulation system (non-solid nature)

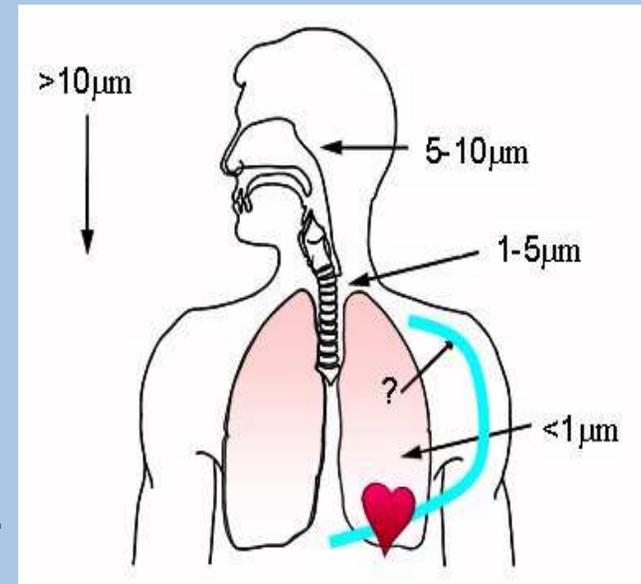


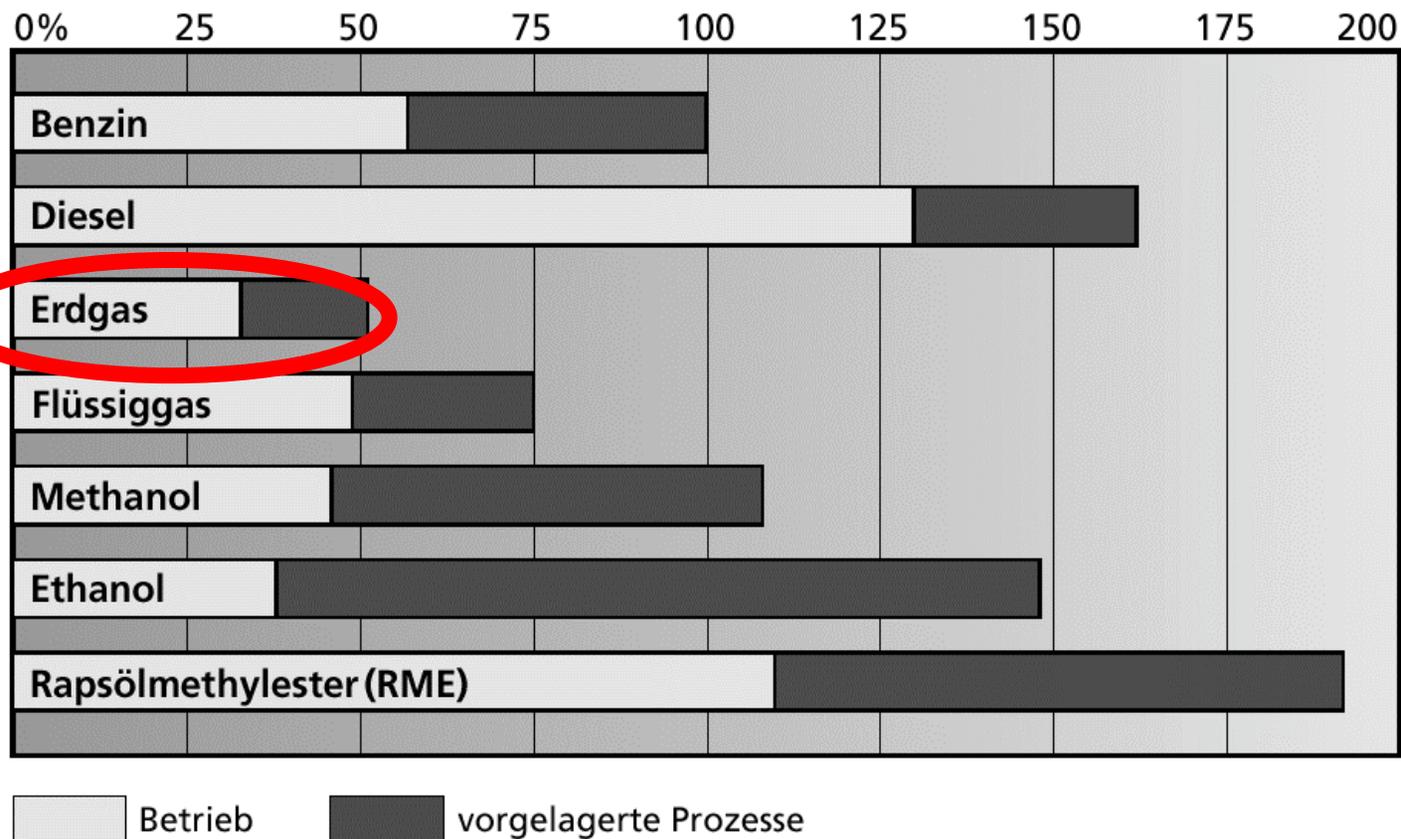
Figure: Sam Altshuler

Source: IANGV BUS EMISSION STUDY
COMPARISON OF EMISSIONS FROM
DIESEL AND NATURAL GAS BUSES, VTT Research Center,
Finland, Nils-Olof Nylund & Kimmo Erkkilä



Pollution Level of Different Fuels

Bewertung der Treibstoffe von Personenwagen nach Umweltbelastungspunkten



Source: GAZNAT



Possible Alternative Automotive Fuels

- Diesel
- Gasoline
- LPG
- Methanol
- Ethanol
- Natural Gas
- DME
- Vegetable Oils / Fats
- Hydrogen

And: Gas to Liquids (GTL) : a promising source for Diesel (FT Diesel)



Hydrogen

- Production from renewable sources foreseen....in the future
- Significant government funding
 - U.S. ~\$1.7 billion FY 04–08
 - Japan ~\$250 mil FY 03-07
 - Europe ~€900 mil... 'into the future'
- H2 & Fuel Cells have *sex appeal* (like electric cars in the 1980s)
- CNG fuelling stations likely will be the pathway to the H2 fuel infrastructure

Source: presentation for UN, januari 2004, Jeff Seisler



H2 Fuel Cell Generator "the Core"

Design by 'intelligent energy', UK

1 kW electricity power unit for all kind of applications





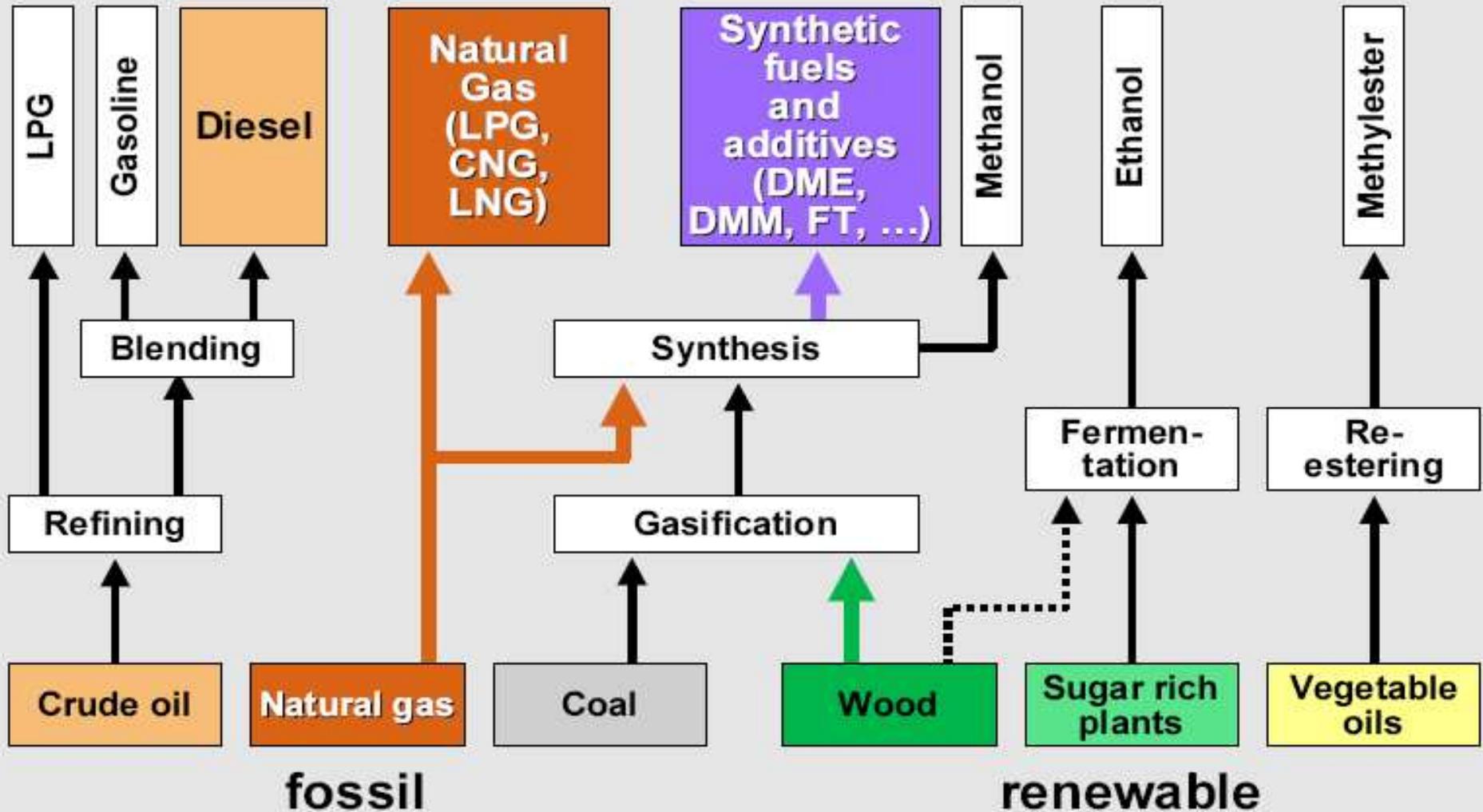
The Core as 'engine' for ENV (emission neutral vehicle)

Launched March 2005, for urban use
1 kW fuel cell, motor 6 kW peak with batteries
Range 160 km, top speed 80 kph, completely silent!





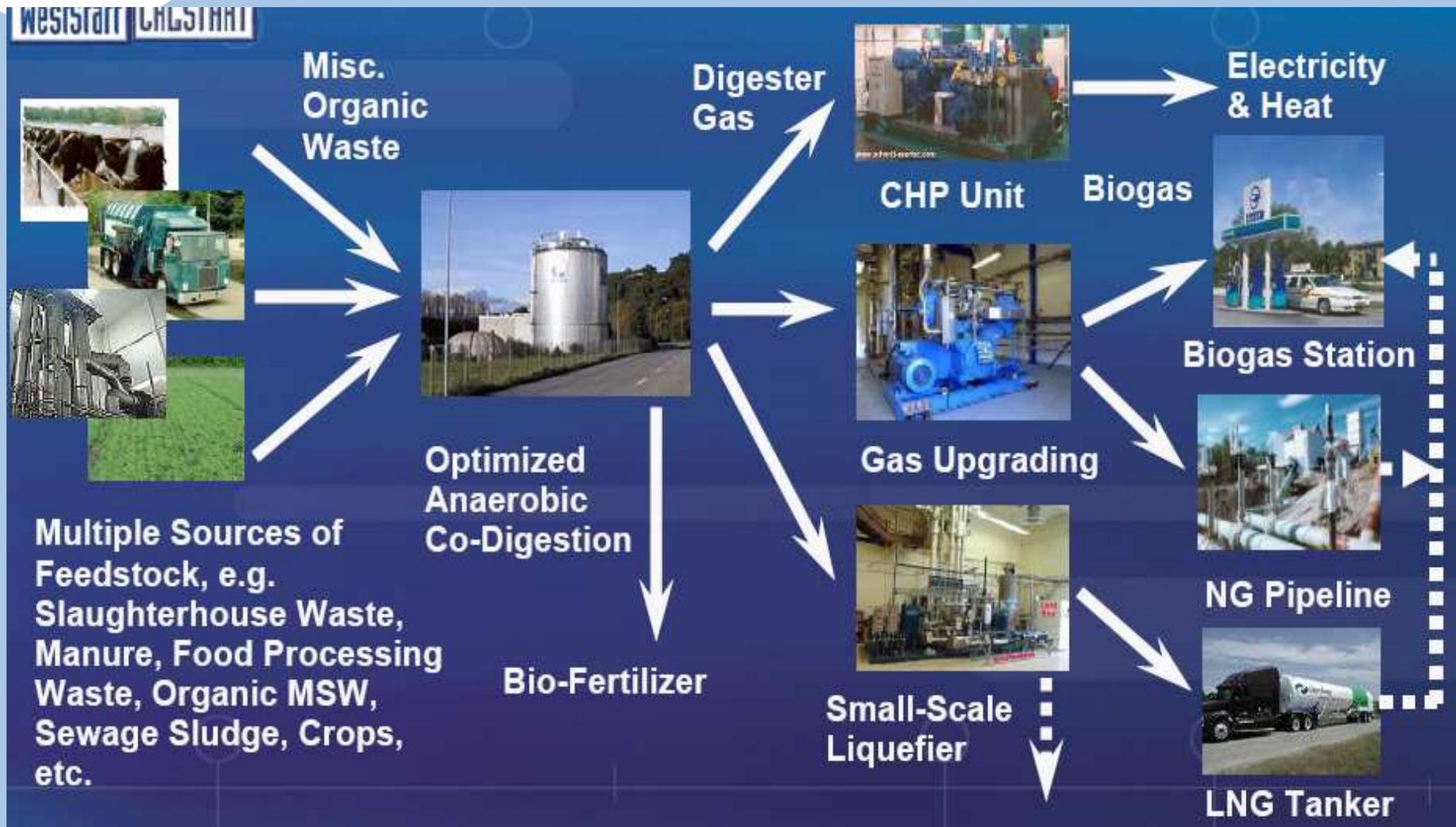
Fuels for Internal Combustion Engines



Source: Gill, Ofner in 9th IEA workshop, Paris, 31 May 2001 'DME as an automotive fuel'



How to Produce Biogas





DME Characteristics

DiMethyl Ether - Acceptability



Commercial Powertrain Systems

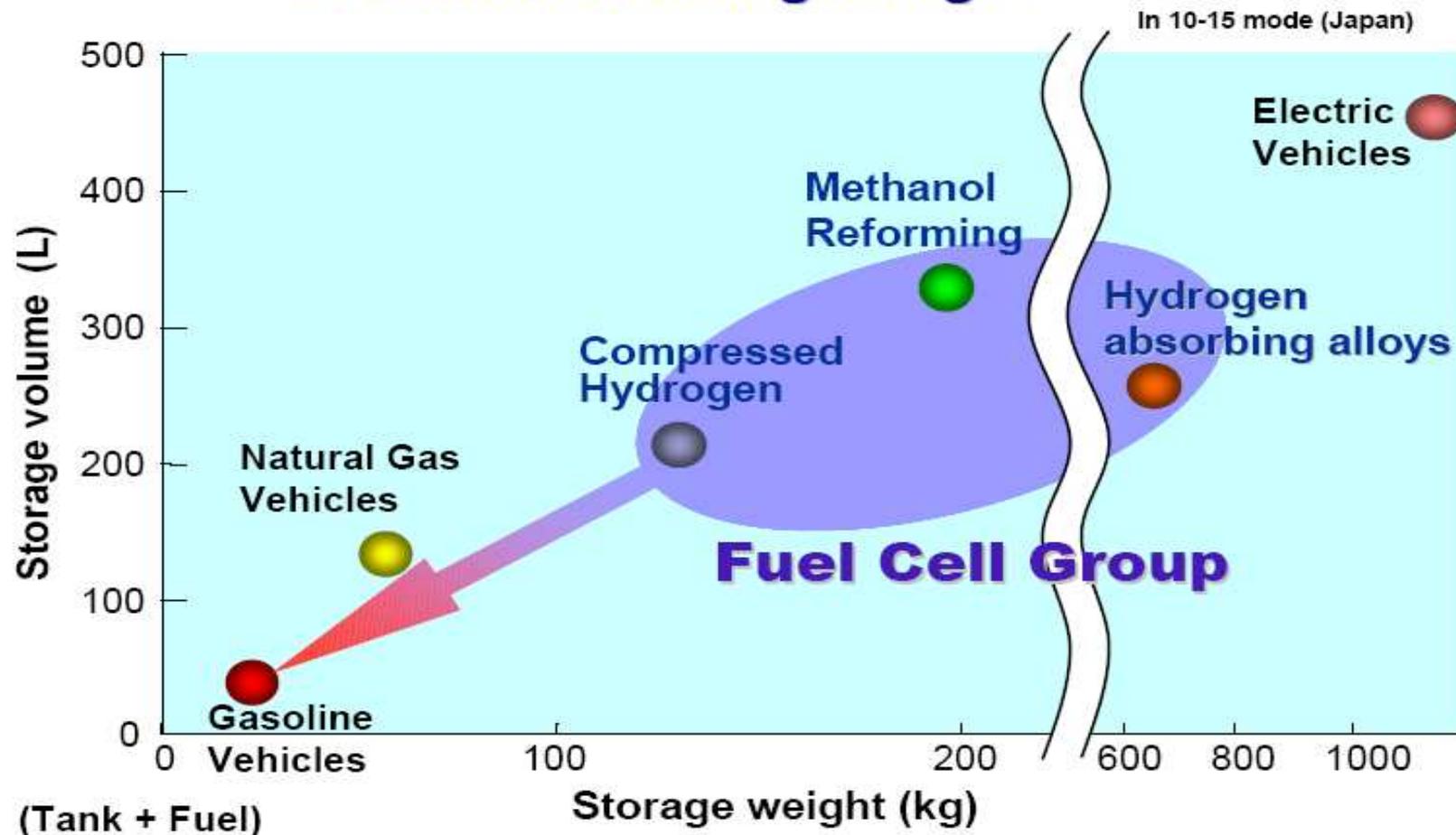
- **Safety**
 - Inflammable Liquified Gas (~Propane/Butane)
 - Heavier than Air
 - Burns with Blue Flame
- **Health**
 - Non Poisonous (MAK: 1000 ml/m³ ~ Propane/Butane)
 - Non Caustic
 - Non Carcogenic
- **Environment**
 - Short Half Life in Troposphere
 - Does not reach Stratosphere
- **Handling**
 - Similar to Propane/Butane



Storing gas in your vehicle takes up volume and payload capacity

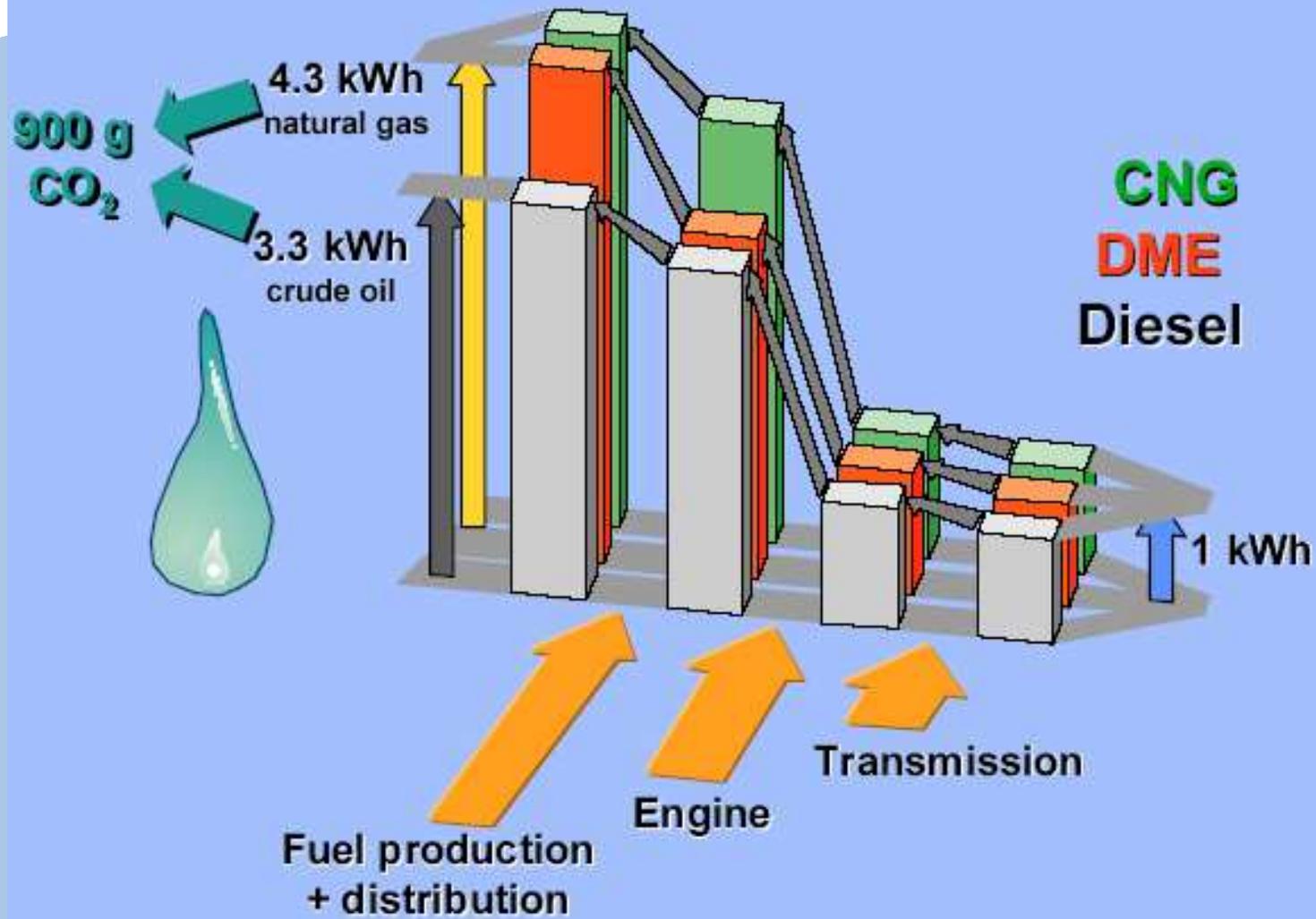
Fuel Storage Capacity vs. Weight at 500km Cruising Range

HONDA
The Power of Dreams



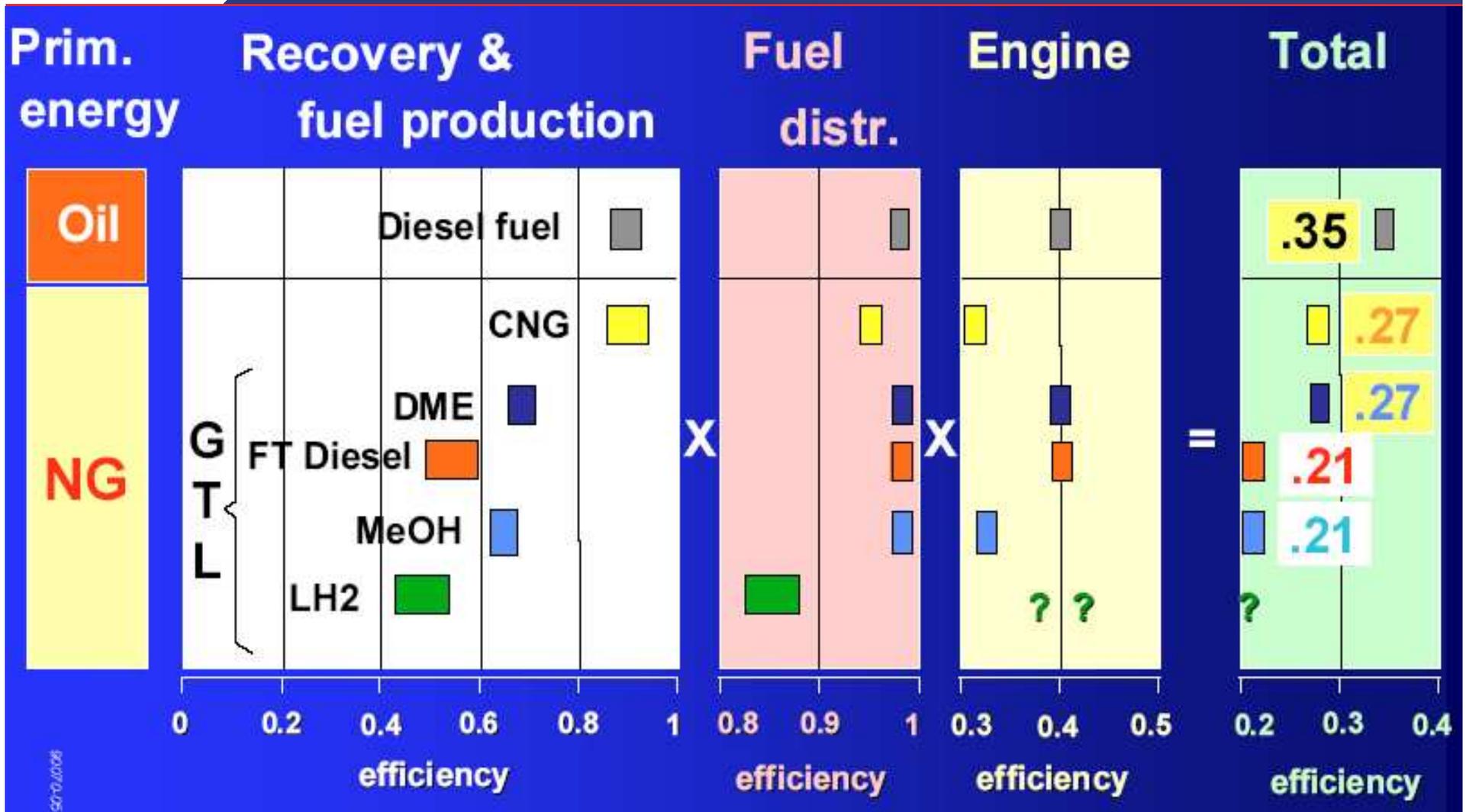


Well to Wheel Efficiencies





Total Efficiencies of Various Fuels



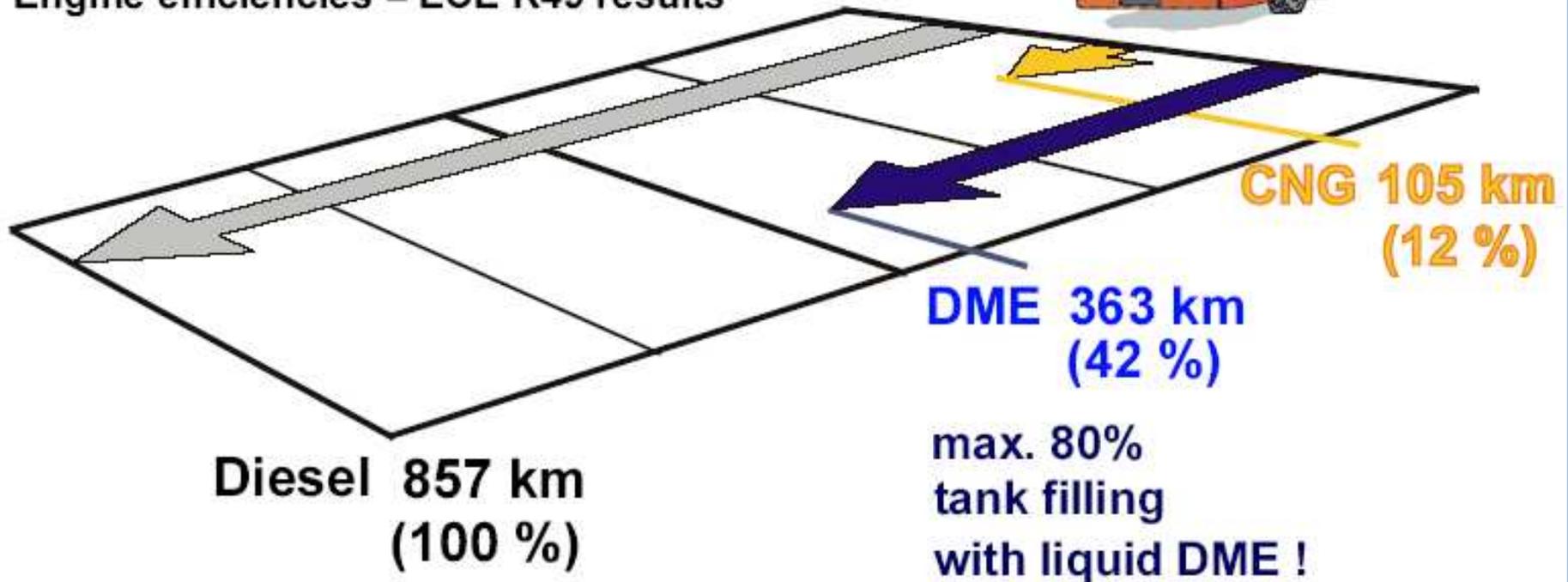
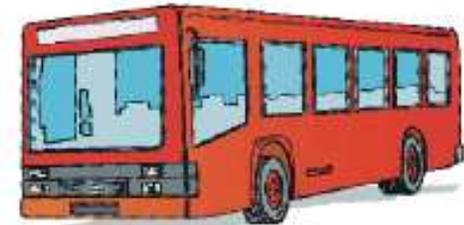
Source: Gill, Ofler in 9th IEA workshop, Paris, 31 May 2001 'DME as an automotive fuel'



Driving Range with Various Fuels

Driving Ranges with refilled 300 lit tank

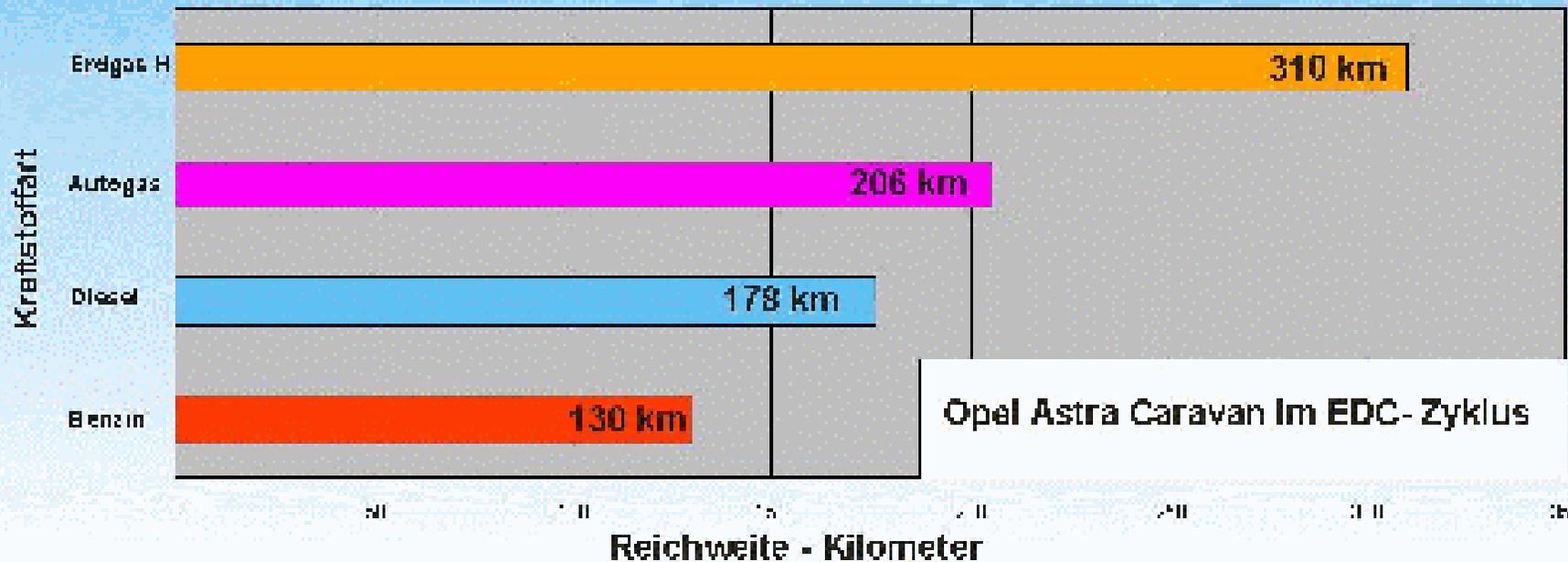
Bus engine, FC = 35 lit Diesel / 100 km
Engine efficiencies = ECE R49 results





How far can you get with € 10

So weit fahren Sie für 10 Euro



Source: Energie Waldeck-Frankenberg GmbH



Experience with Incident

(pictures ENGVA)



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

SEVERE ABUSE TESTING

Car drops from...
10 ...17....23...30 metres and no leakage



Extreme US Tests Prove Safety of Gas Cylinders

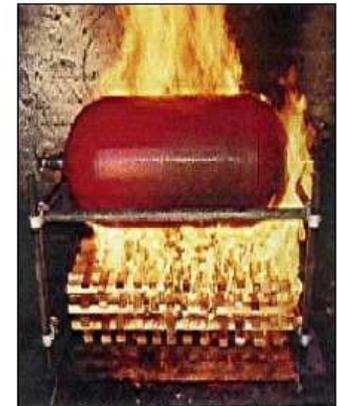
NGV SAFETY: SEVERE ABUSE TESTING OF CNG CYLINDERS

CNG CYLINDER SEVERE ABUSE TEST

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



Dynamite Test



Bonfire test

Source: ENGVA



Fuel Comparisons

(value judgements)

Fuel		Safety	Economy	Technology	Environment
Gaseous	Natural gas	●	●	◐	●
	LPG	◐	●	◐	◐
	Hydrogen	○	n/a	n/a	●
Petroleum	Gasoline	◑	●	●	◑
	Diesel	◐	●	●	◑
Alcohol	Ethanol	◑	○	◐	●
	Methanol	○	◑	◐	◐
	DME	○	◑	◑	◐
Synthetics & biomass	FT gasoline	n/a	n/a	n/a	n/a
	FT diesel	n/a	n/a	n/a	◐
	Bio diesel	◐	○	●	◑
Electricity		●	n/a	○	*●

Legend:

Best

Worst



* The environment performance of hybrid vehicle is equal to LPG performance.

Source: ENGVA



Experience with Gas-on-the-Road will pave ways

- **For green gas (bio gas) in vehicles**
 - same technology as natural gas
- **For fuel cells to replace internal combustion engines**
 - same storage technology but different engine
- **For hydrogen**
 - fuel cell but different storage technology (very high pressure or metal hydride)



Some Statistics

(approximates)

- **700 mln cars in the world**
 - annual production capacity of cars 60 mln
 - in highest developed economies 0,5 car per capita
- **4 mln NGV's**
 - 1,3 mln in Argentina, 0,9 mln in Brazil
 - 475.000 in Pakistan
 - 220.000 in India including 120.000 three-wheelers
 - 400.000+ in Italy
 - 97.000 in China (half of this buses)
 - 350 in The Netherlands (also 8 NG-boats)
 - *Large NGV countries employ 1 refuelling station per 1000 cars*
 - *Annually 10 bcm is consumed by NGV's*



Some Statistics (2): Number of NGV's in Asia

- 475.000 in Pakistan**
- 220.000 in India** including 120.000 three-wheelers
- 97.000 in China** (half of this buses)
- 33.500 in Bangladesh**
- 22.000 in Japan**
- 12.300 in Malaysia**
- 6.500 in Korea**
- 5.000 in Indonesia**
- 4.300 in Thailand**



Natural Gas Bus in Zigong



Natural Gas Bus in Zigong

There is an abundance of natural gas in this part of Sichuan. All of the local buses in Zigong use natural gas to fuel. The bags of rubber on the top of the bus contain the gas. The sheer weight of the bag forces the gas into the engine. From time to time the buses stop at a station to get a fresh supply of gas. Certain parts of China have natural gas but China doesn't have much in the way of pipelines to distribute the gas to other parts of China.



Delhi CNG Three-Wheeler





EUROPEAN ALTERNATIVE FUELS POLICY

% Fuel Replacement, Transport Sector, 15 EU Countries by 2020

[] = Optimistic

Year	Biofuel	CH4	H2	Total %
2005	2			2
2010	6	2		8
2015	[7]	5	2	14
2020	[8]	10	5	[23]



Situation in a few EU Countries

Italy : *already a mature market, but developing further*

- State promotion of alternative energies since first oil crisis
- present number of fuelling stations : 471
- present number of NGV's: 434'000

Germany : *in active development*

- State support : fuel tax reduction until 31.12.2020
- Active promotion by the gas industry
- Present number of CNG stations: 565 objective 2007: 1'400
- Present number of NGV's: 27'000 objective 2007: 500'000

France : *in active development*

- Concentration on public transport and large fleets
- 7200 cars and 1400 buses
- New program: individual CNG fuelling stations at home

Austria : *starting*

- State support : fuel tax reduction until 31.12.2020
- 400 vehicles and 24 CNG stations

Source: GAZNAT



Deutsche Ente mit Gasantrieb (German Duck with CNG)



Source: www.winni-the-pooch.de/auto/gas.htm#foerderung



Blue Corridor in Europe



Vernadsky
Foundation

The Blue Corridor Project





Blue Corridor (2)

- **10.500 trucks and buses**
- **Conversion from diesel to CNG, LNG, dual fuel**
- **Goals: reduction of emissions (health threatening particulates), fuel diversification**
- **State of art: final report to UN's economic commission for Europe; project not executed yet**



US-Canadian Trucks on LNG



- **“Clean Air corridor”**: Westport’s HDPI Natural Gas Engines mounted into 5 Volvo trucks for transport Ontario – Michigan
- **500 miles range Project just started**
- **4-year of good experience with 13 waste trucks in San Francisco, same technology**
- **Technology: small amount of diesel to provide ignition, bulk fuel is LNG**



Natural Gas Bus in L.A.



Los Angeles Metropolitan Transportation Authority's CNG-fueled "Metro Liner" buses are powered by the low-emissions Cummins Westport 320-hp L-Gas Plus engine.



NGV Opportunities

For society at large:

- **Short time: clean cars on city streets**
- **Medium term: fuel diversity in road transport**
- **Very long time: alternative for exhausted oil reserves (H₂, bio-gas)**

For gas industry: new market, but only attractive if premium prices apply



Why should we promote CNG ?

Public interest:

- **Environmental reasons**
 - Less pollutants emitted
 - Less engine noise
- **Diversification of automotive fuels**
(EU: 10% gas in 2020)

Advantages for the gas industry:

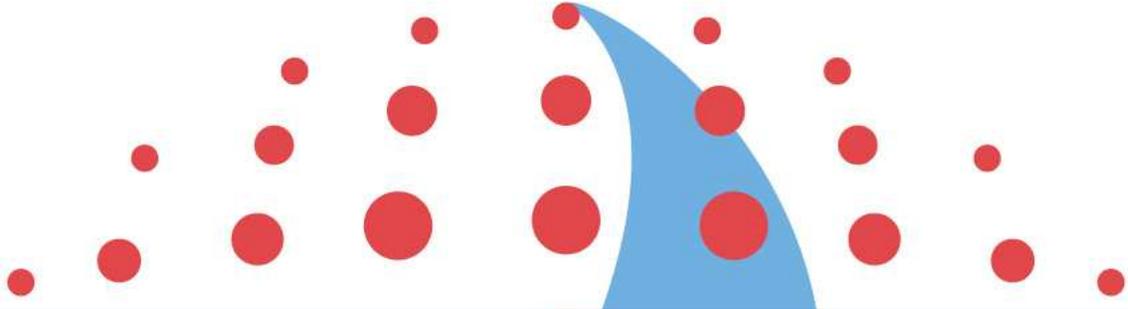
- **New market**
- **Better use of gas infrastructure**
- **Image (promotion for natural gas in general)**



Chicken and Egg?

- **No refuelling stations - no long distance travel by NGV**
- **No NGV's – no investors in refuelling stations**
- **So: start with local traffic: urban buses, municipal fleet – 1 refuelling station will apply**
- **Build up NGV market from these kernels to regional/national/international level**
- **Important for public confidence in future of NGV's: guarantees from government for taxes on cars and duties on fuel**

2006
IGU



**Thank you,
for your attention**



See you in Amsterdam!
**23rd World Gas Conference and
Exhibition**
June 5 – 9 2006

