

# Links and Gaps in the NGV Safety Chain: An Overview of NGV Safety Perceptions & Realities

Dr. Jeffrey M. Seisler, CEO



## CNG & LNG Safety: Perception & Reality

8-9 October 2014

Brussels, Belgium

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# Scope of the presentation

- Common perceptions of natural gas safety: CNG & LNG
- The realities of natural gas safety: CNG & LNG
- Safety along the NGV supply chain
- Global NGV safety: Tying up the loose ends

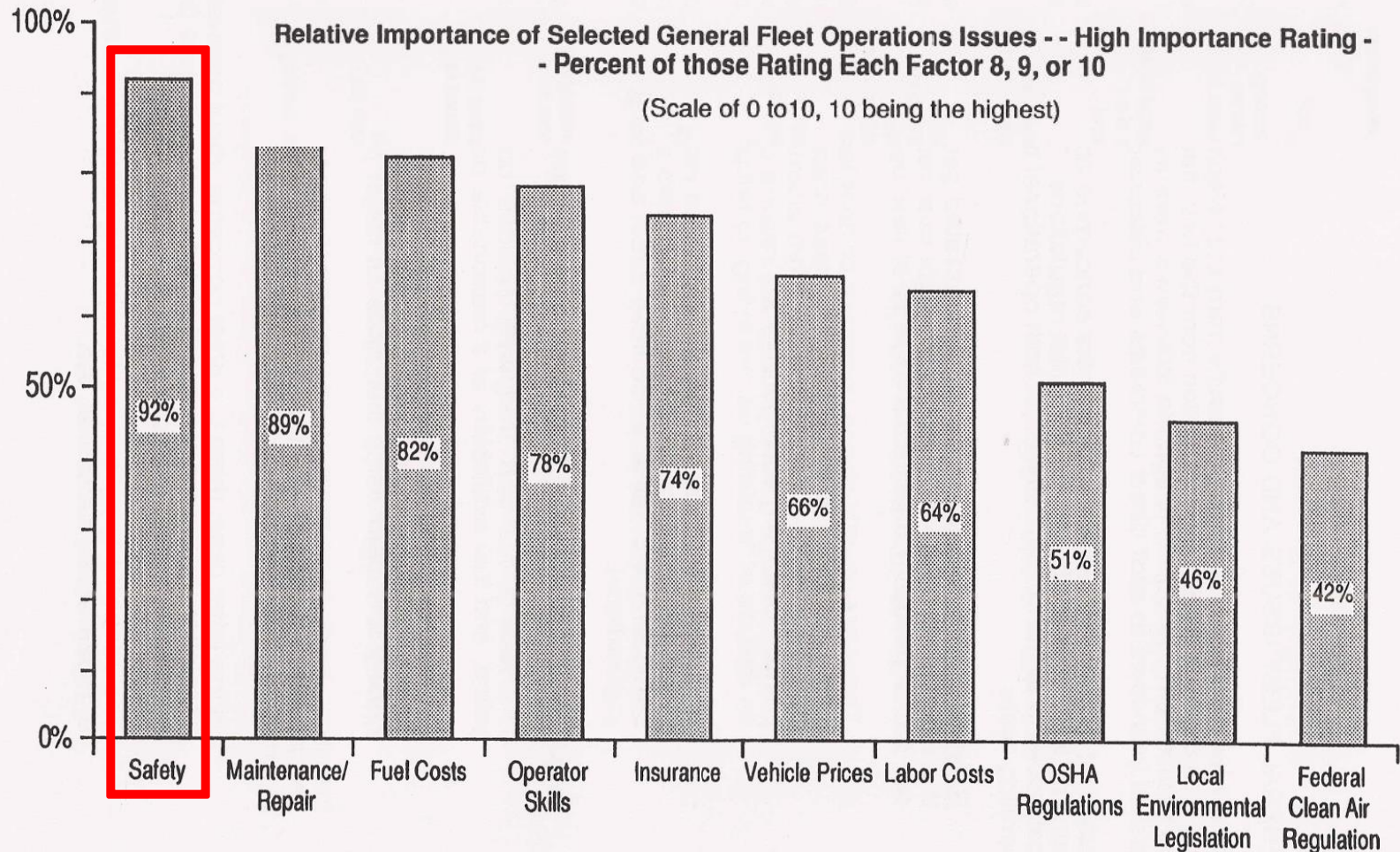
# COMMON PERCEPTIONS OF NATURAL GAS AS A VEHICLE FUEL Past & Present



Perception is Reality



# Safety: the most important operations issue for fleet operators (in the U.S.) 1991

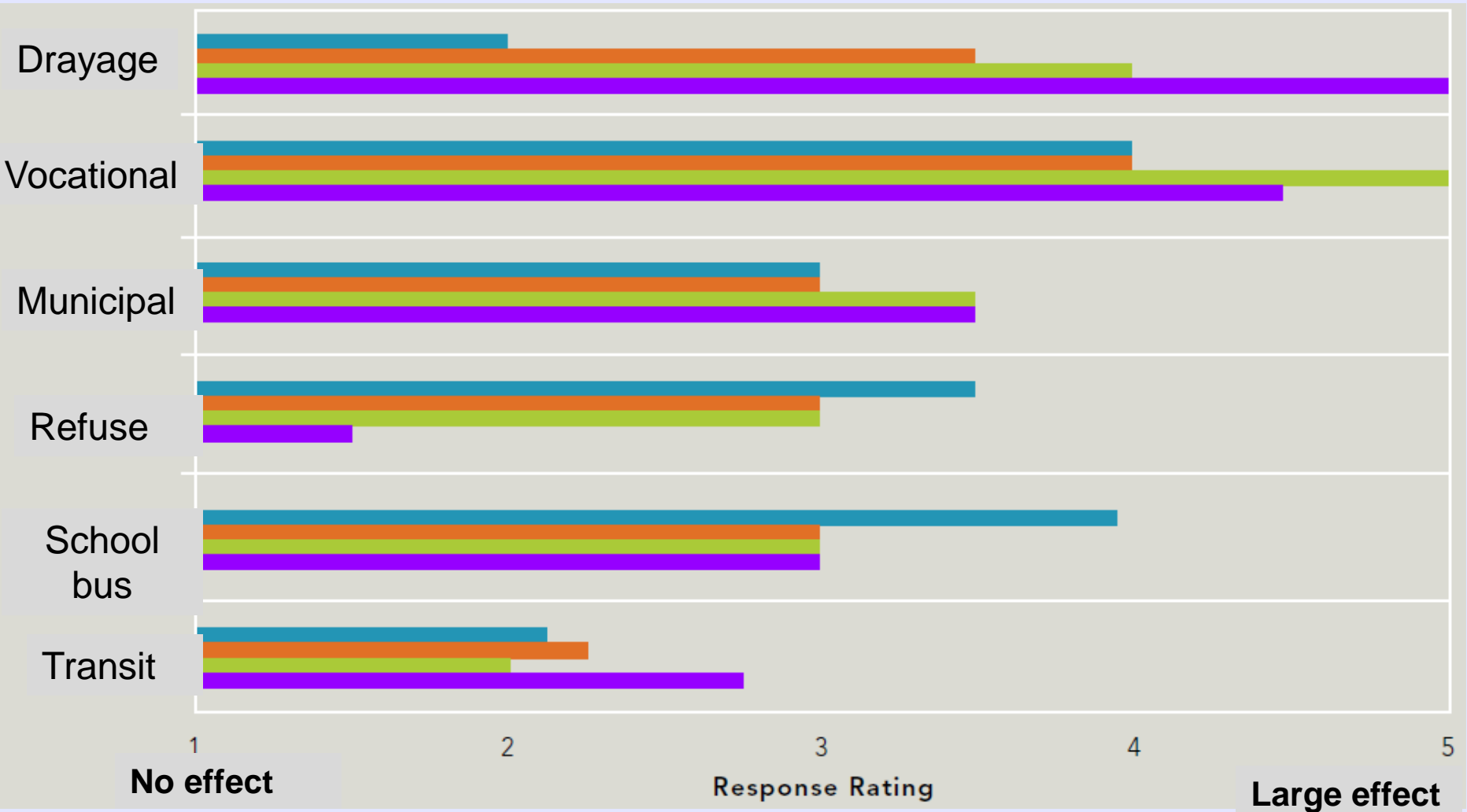


Source: American Gas Association & NGV Coalition Fleet Survey, 1991, (telephone survey of 500 fleet operators)

# Different types of U.S. fleet operators rated their concerns about NGVs (2012)

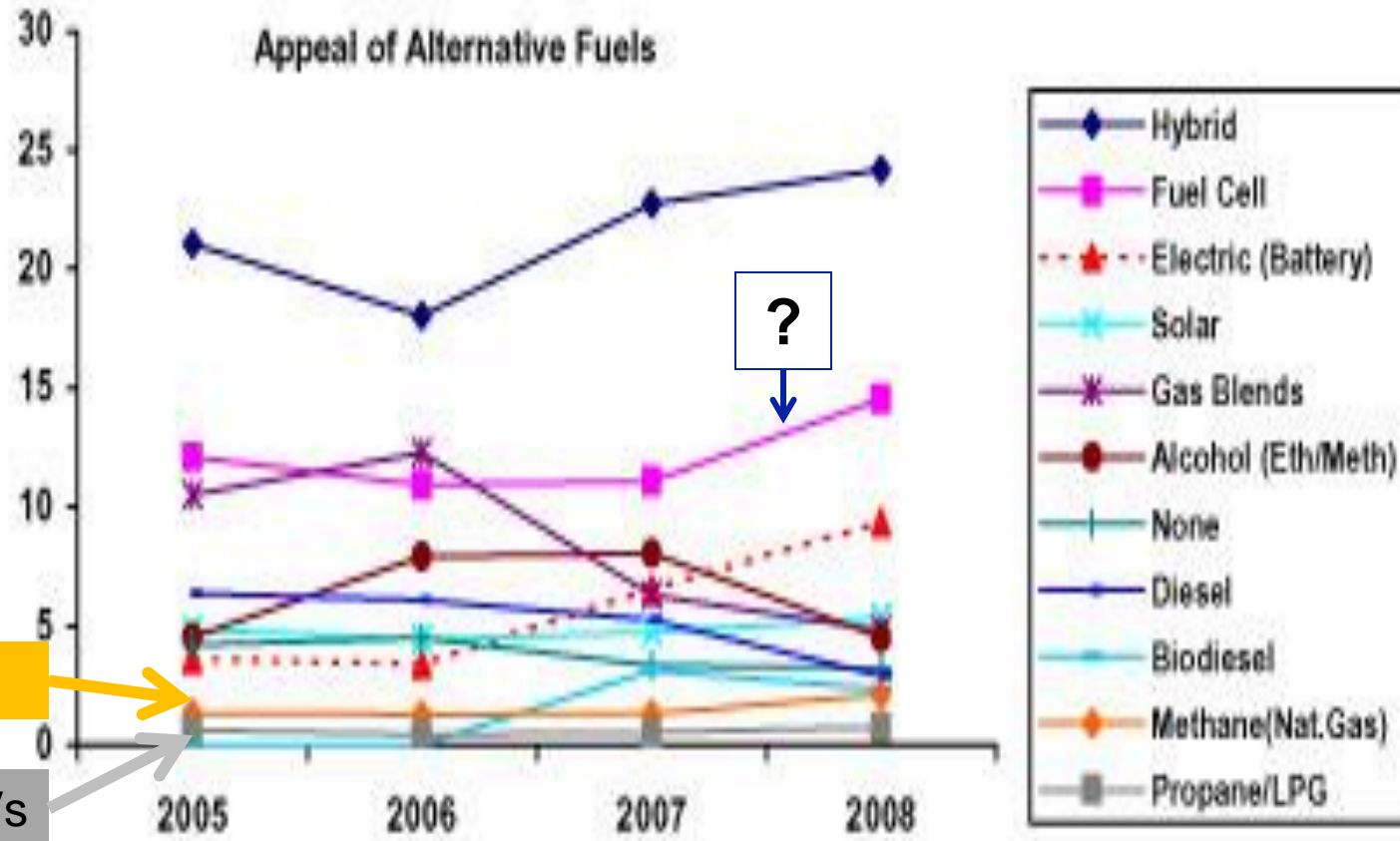


safety - range - weight/space - performance



U.S. and Canadian Natural Gas Vehicle Market Analysis: Heavy-Duty Vehicle Ownership and Production, Final Report, Tiax, for the American Natural Gas Alliance, 2012, from NAFA survey of 200 fleet managers.

# Despite being world market leaders amongst alternative fuels, in the U.S., NGVs and LPG-Vs are least appealing



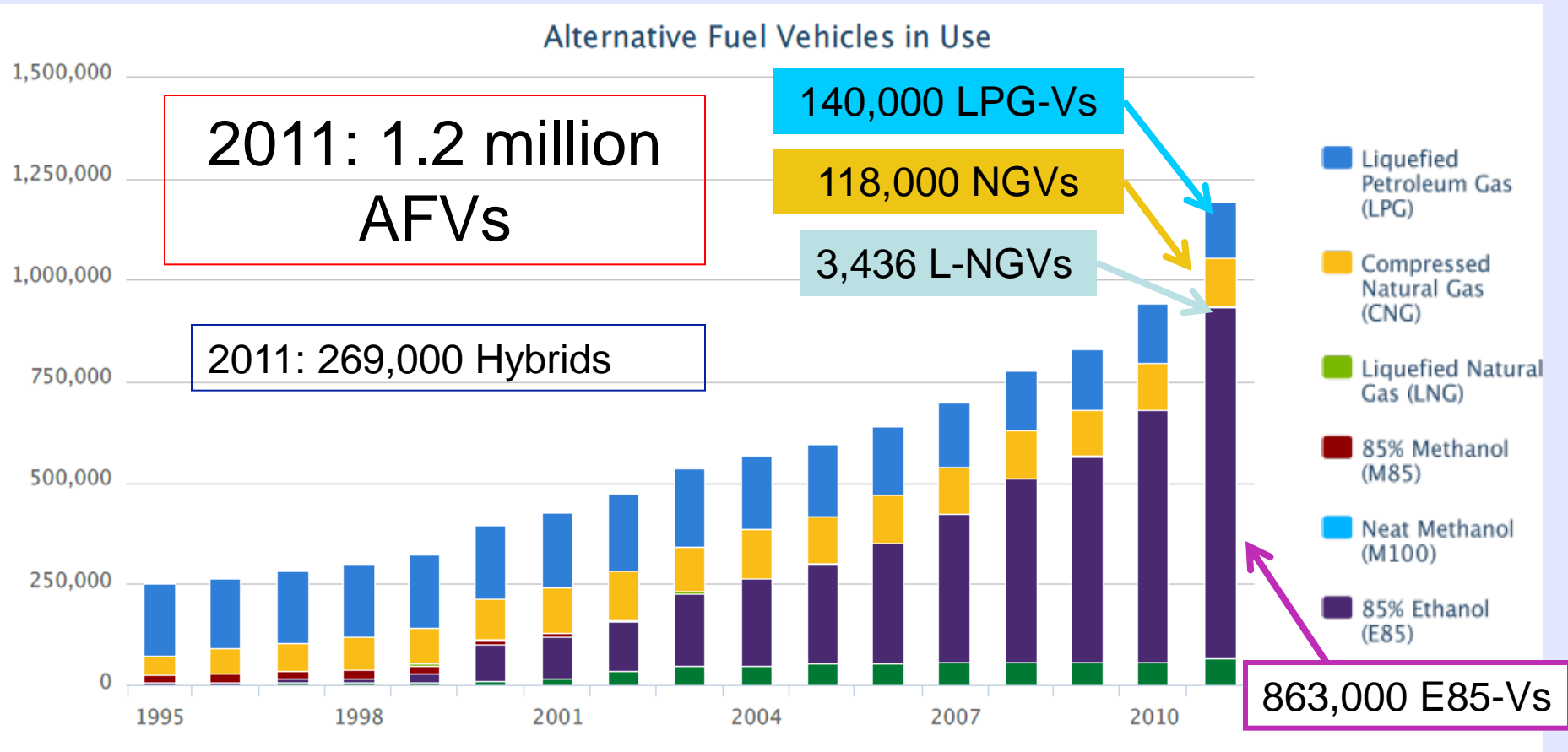
NGVs

LPG-Vs



Individuals were asked by Maritz which alternative fuel vehicle they would prefer out of 11 choices.  
Credit: Maritz Automotive Research Group, 2011. telephone survey of 1,207 licensed American drivers 18 years of age or older

# U.S. Alternative Fuel Vehicles 1995-2011

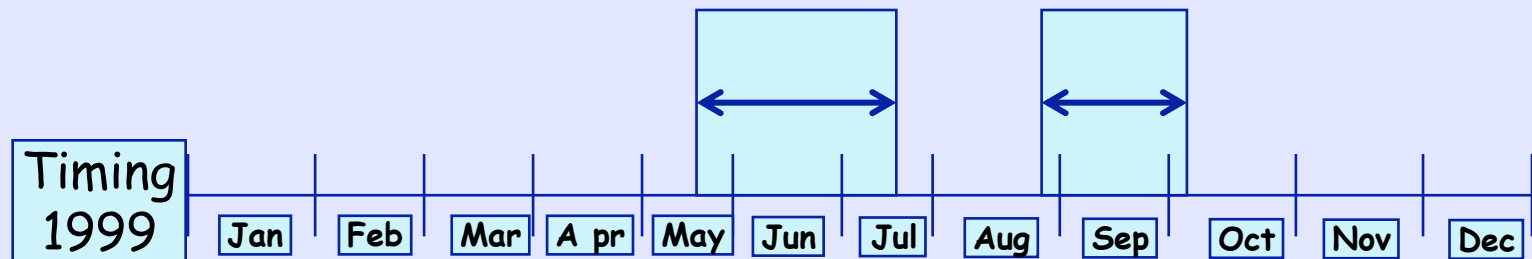


Alternative Fuels Data Center, U.S. Energy Information Administration,  
<http://www.afdc.energy.gov/data/10300>



# 1999 Italian NGV Campaign surveyed 800 people, representative of the Italian drivers population (Eurisko marketing survey)

Media Campaign: 3 main newspapers; 8 weekly magazines; 25 monthly magazines (car, science, environment, life style)

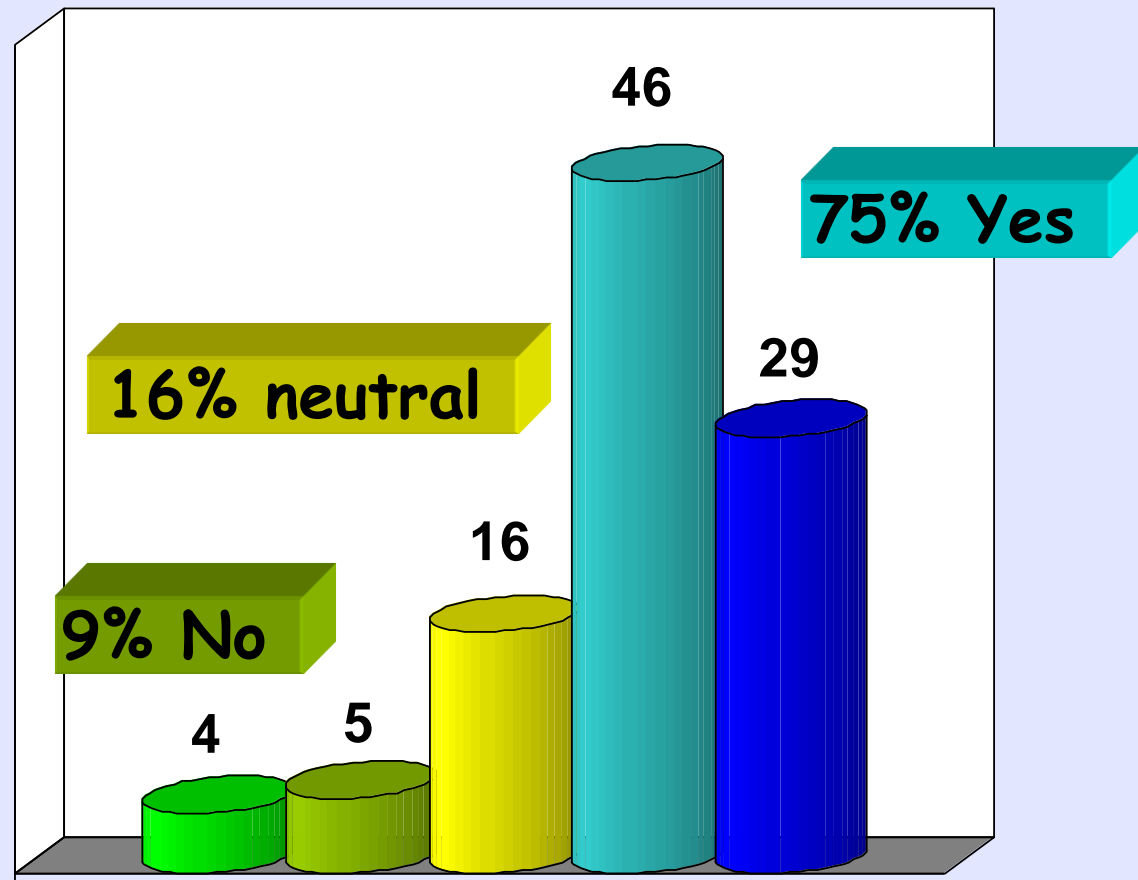
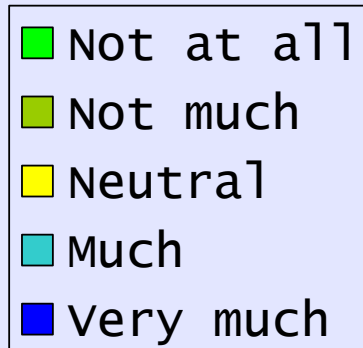


Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium



# Do you think CNG is an attractive motor fuel?

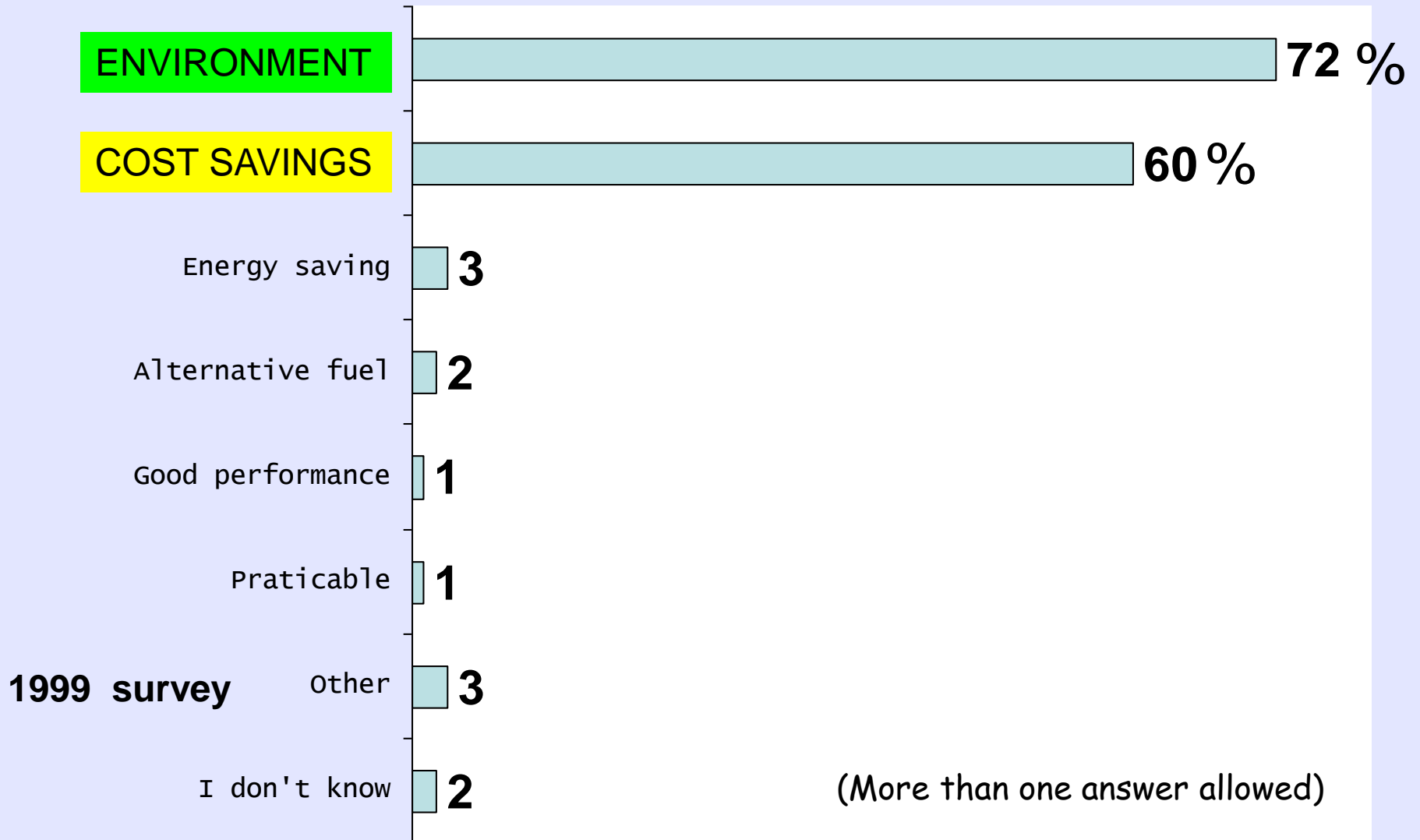
1999 survey



Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium



# Why do you think CNG is attractive?

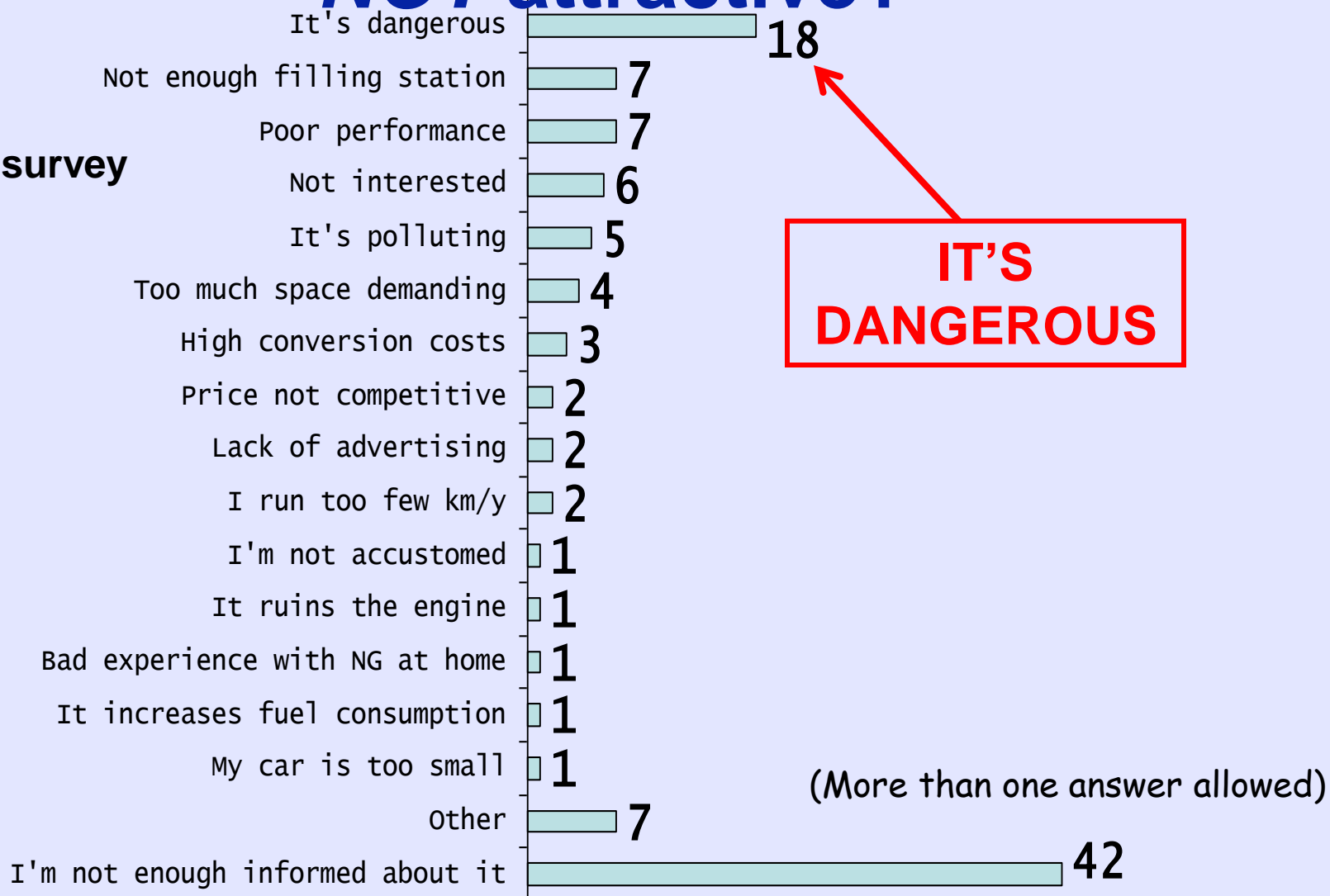


Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium

# Why do you think CNG is *NOT* attractive?



1999 survey

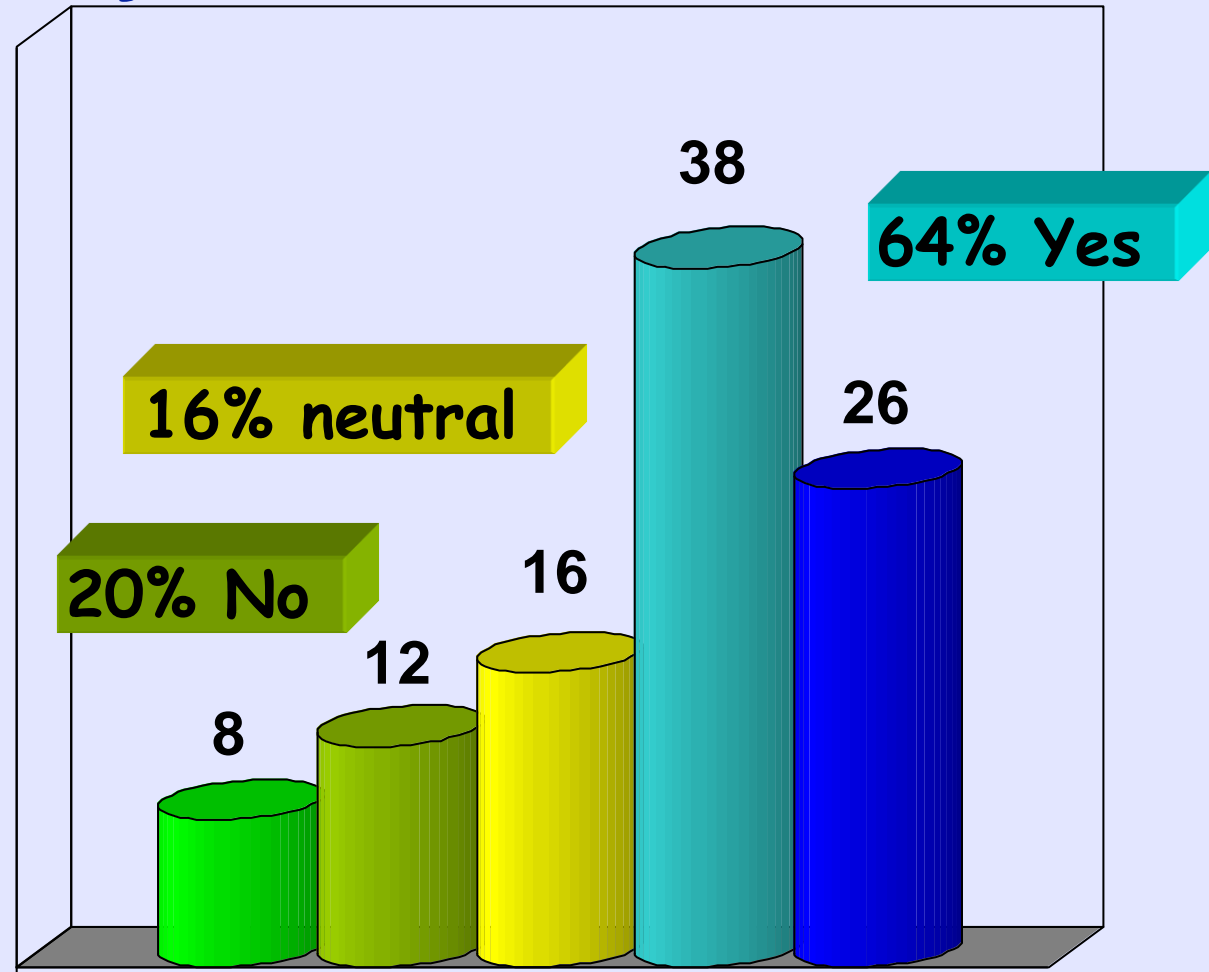
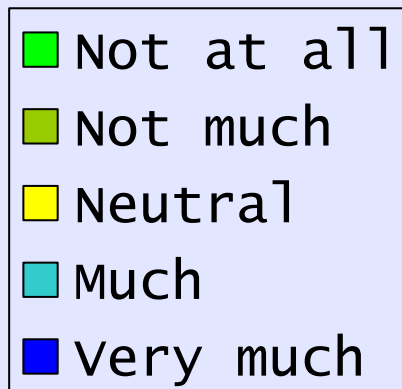


Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium



# Would you be interested in CNG for your own car?

1999 survey

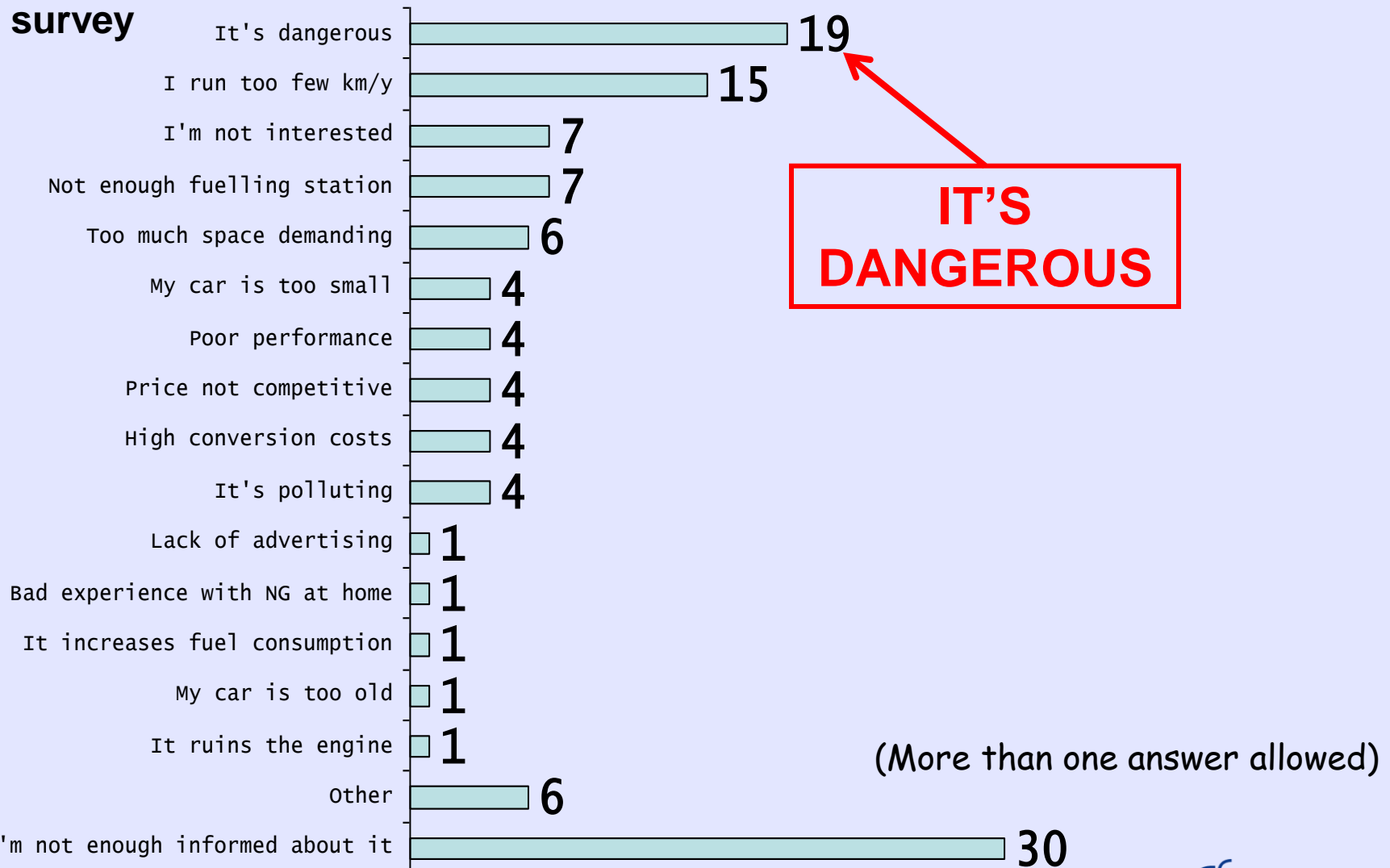


Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium



# If not, why?

## 1999 survey

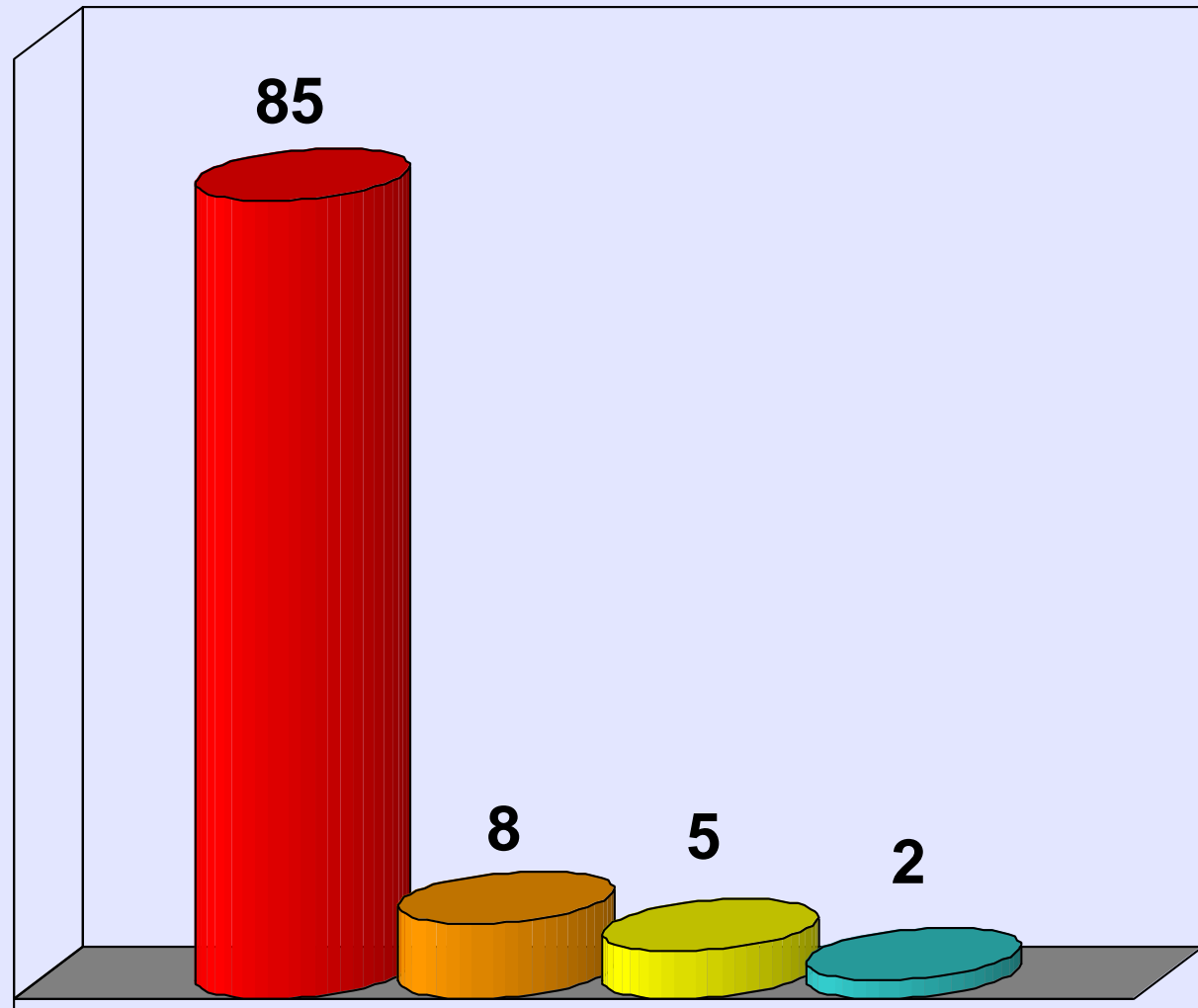
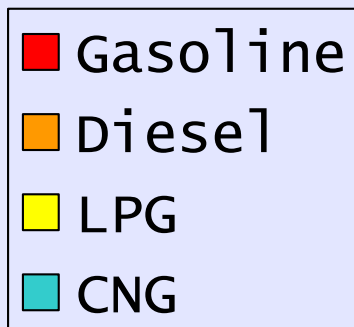


Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium

# What's your fuel now?



1999 survey

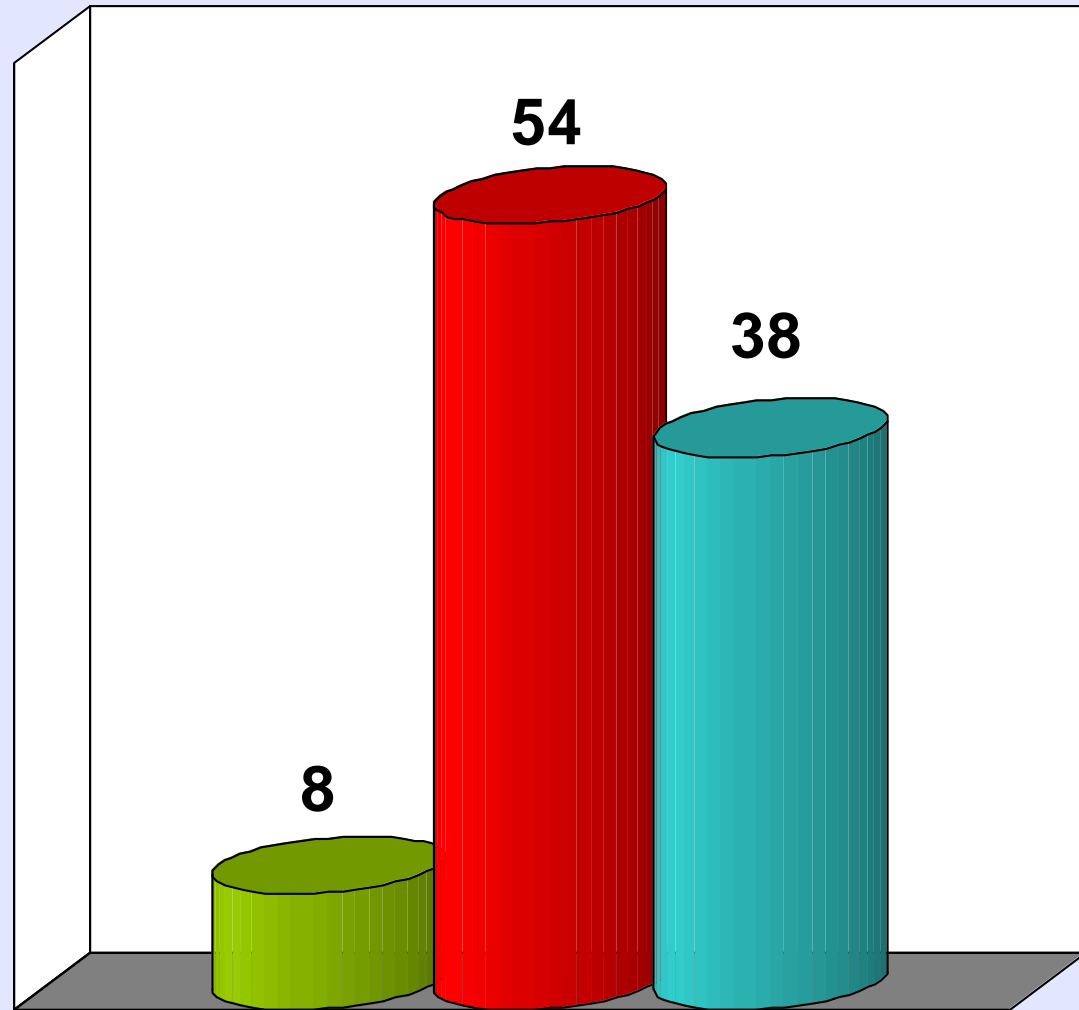
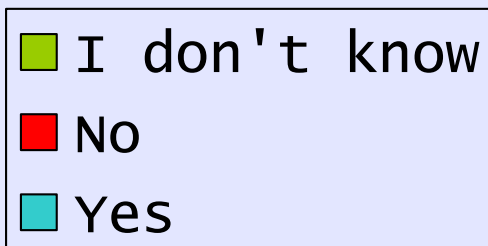


Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium

# Would you be interested in converting your car to CNG?

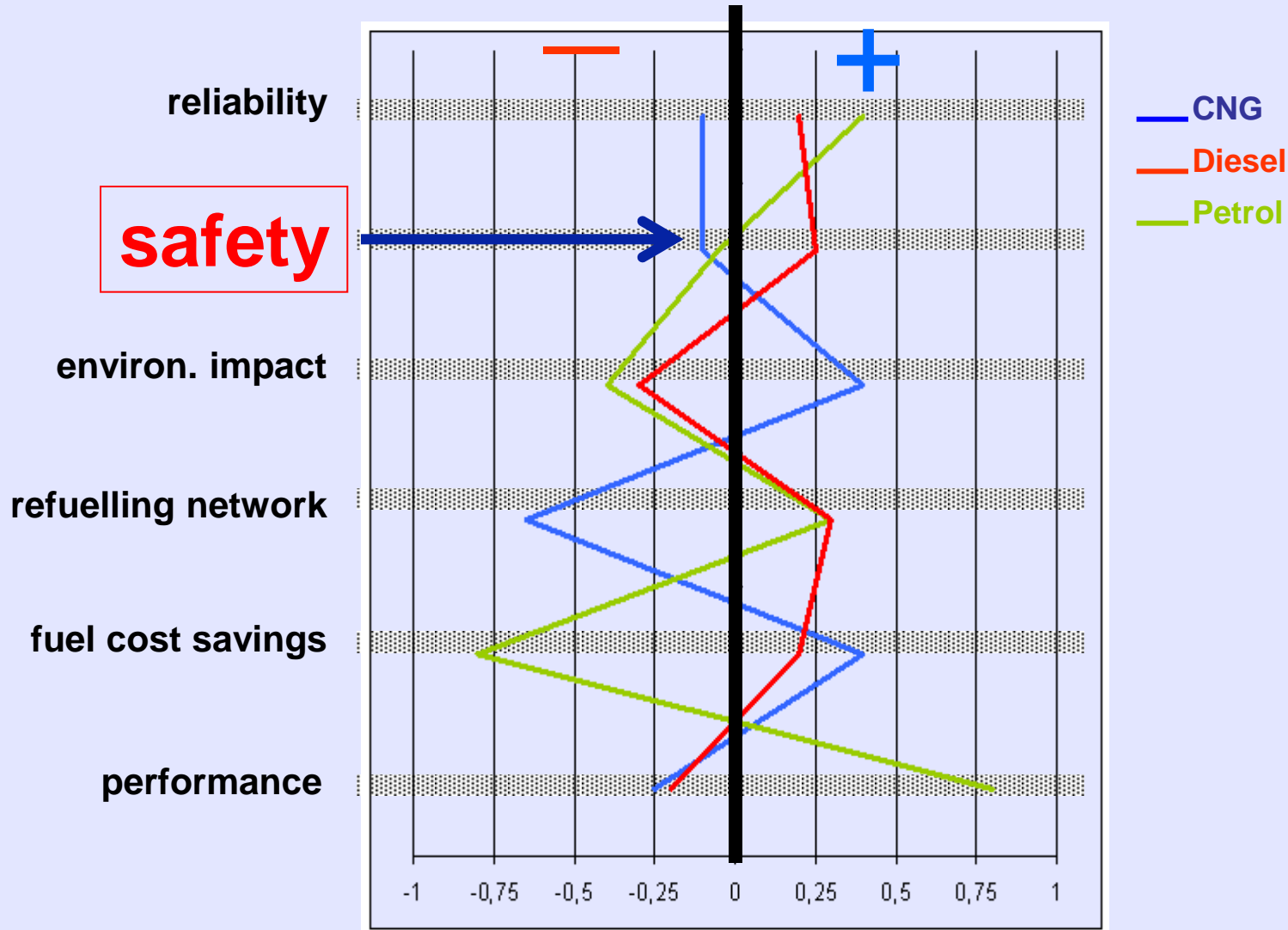


1999 survey



Source: The NGV Market in Italy, Flavio Mariani (ENI) as presented at the 2002 Bayerngas Symposium

# Italian customers' appreciation of NGVs: Safety was a preceived issue in 2005



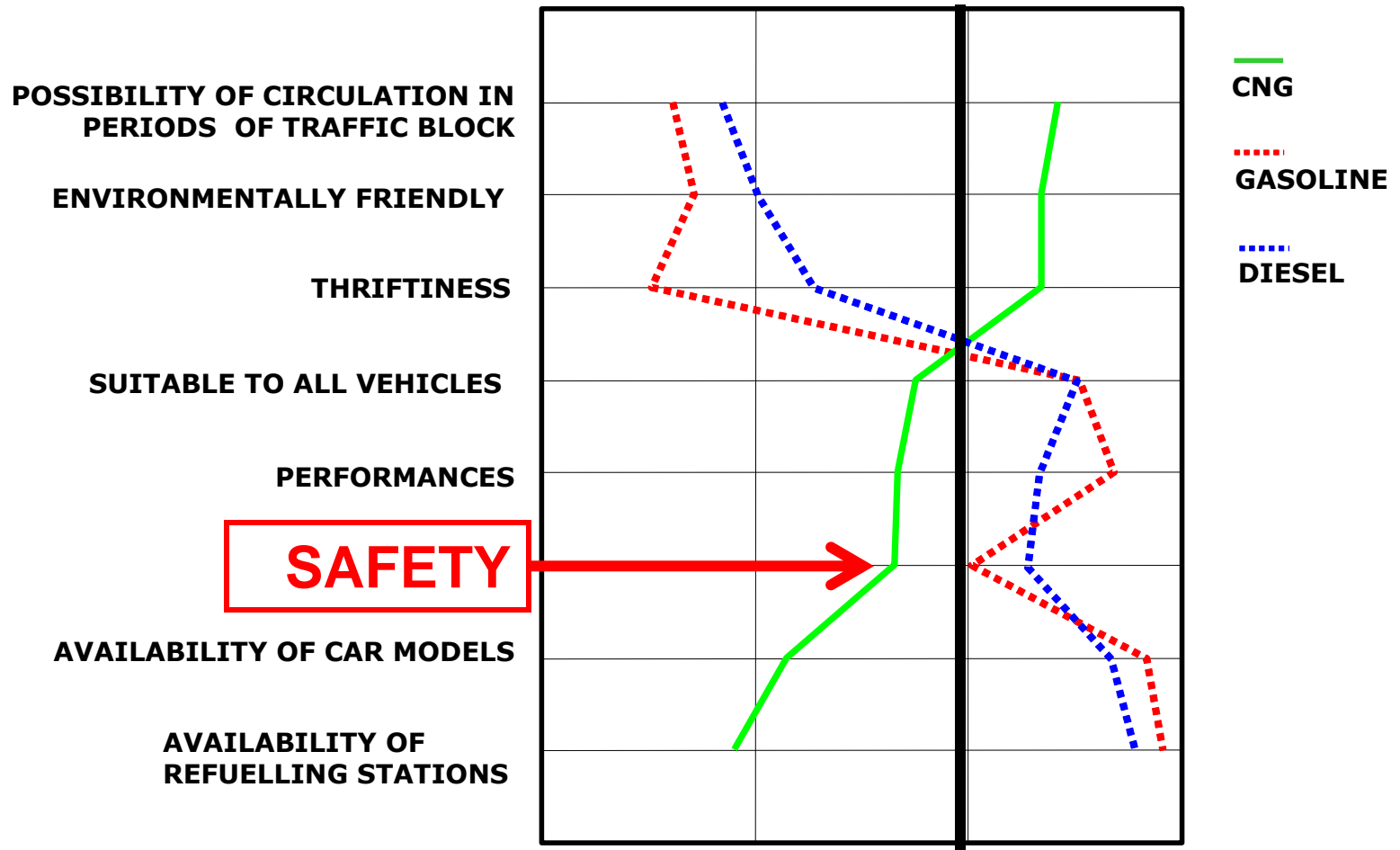
Source: Italian NGV Scenario 2005, Flavio Mariani, Metauto-ENI Divisione Gas & Power, Cattolica, September 20-21, 2005



# Fleet operators opinion survey

## Perception of CNG features vs gasoline and diesel

NEGATIVE SCARCE ACCEPTABLE GOOD



Source: Italian NGV Scenario 2005, Flavio Mariani, Metauto-ENI Divisione Gas & Power, Cattolica, September 20-21, 2005

# What is the regulators' perception of NGVs?: Tunnels

- After May 1949 gaseous fuel trucks were illegal in New York tunnels (also Boston)
- A tank truck carrying highly flammable *carbon disulfide* was in a 10 truck accident in the Holland Tunnel linking New York City and New Jersey. 69 people injured; 1 death;



# What is the regulators' perception of NGVs?: Underground Parking

REGULATIONS  
EXIST

Parking  
Allowed

Italy  
Ukraine  
U.S.A

Parking  
Forbidden

Hungary  
Slovakia

NO  
REGULATIONS

Parking  
Allowed

Austria  
France  
Germany  
Sweden  
UK

Parking not  
forbidden

Croatia  
Belgium  
Netherlands  
Spain

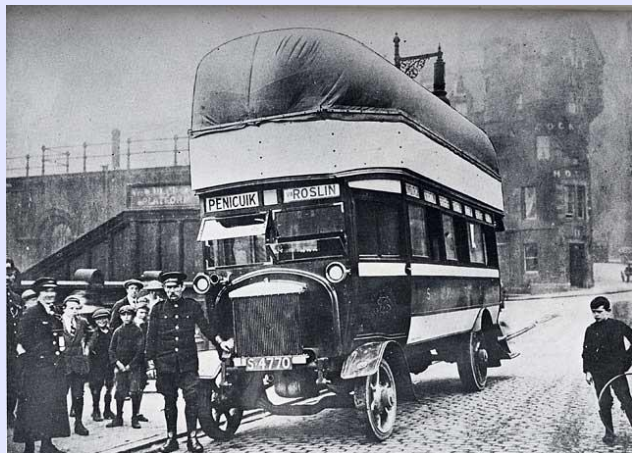
# NATURAL GAS SAFETY



# Properties of Natural Gas

Property	Natural Gas	Gasoline	Diesel
Physical State	Vapor	Liquid	Liquid
Ignition Temperature	1,080 °F	540 °F	410 °F
Density	22 Grams/Cubic Foot (Lighter Than Air)	2,800 Grams/Gallon (lighter than water)	3,200 Grams/Gallon (lighter than water)
Spill Behavior	Evaporates and Disperses	Pools on Surface	Pools on Surface
Storage Temperature	CNG: Ambient Temperature LNG: Below -200 °F	Ambient Temperature	Ambient Temperature
Strong Pressure	CNG: 3,000–3,600 psi LNG: Varies	Ambient Pressure	Ambient Pressure

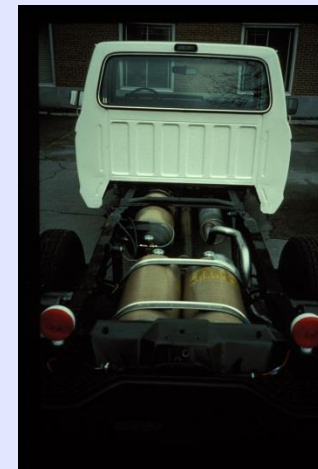
# CNG storage technology has been a focus of safety



Scottish Motor Traction Bus,  
Edinburgh 1914-1918



Citroen 1941



Dedicated Ford  
Ranger: 1<sup>st</sup> Type II  
Cylinder- 1983



Chinese buses 1988



The Wikov NGV,  
Czechoslovakia 1936



CNG Cylinder Severe  
Abuse Test 1983

# The reality is that, when there is a failure of a high pressure fuel cylinder (or LNG tank) the results can be dramatic.



Bus fire in Montbéliard, France (2005) resulted in cylinder melt-down & launching one through the roof of a home



LNG tanker accident Zarzalico, Spain 2011



Dutch bus with 'flame-thrower effect' Wassenaar, NL Oct.2012

# NGV safety has been proven in many situations



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



**The meltable fuse did its job**



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



**The valve melted away**

# Public relations for NGV safety gets started in 1983



**Norm Fawley, President  
CNG Cylinder  
Corporation  
(Long Beach, CA) created  
the 12 minute 'Severe  
Abuse Test' safety video  
1983**



**The Rally for Fuel Savings  
crossed America in 1984  
and 1986 publicizing NGVs  
and the safety of CNG  
(American Gas  
Association)**

# CNG CYLINDER SEVERE ABUSE TEST

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



# NGV SAFETY: SEVERE ABUSE TESTING OF CNG CYLINDERS



**Dropped Cars**



**10 ...17....23...30m drops  
...no leakage!!**



**Dynamite Test**



**Gunshot Test**



**Structural composites  
industry, fire proof cylinders**

**CNG cylinders remain intact under the most rigorous conditions**

# SEVERE ABUSE TESTING

Car drops from...

10 ...17....23...30 metres and no leakage



# U.S. DOT study systematically characterized NGV/CNG accidents, equipment failures & fires from 1976-2010



- **138 incidents:** 56% U.S.; 44% Europe, Asia, S.America
- **All vehicles included:** 51% LDV/Trucks; 38% buses; 11% other commercial vehicles
- Most problems were with individual NGVs
- Some systemic problems identified, especially with Pressure Relief Devices (PRDs)
- 12% involved fire but most not attributed to CNG systems or NGVs (leaking petroleum liquids)

*Natural Gas Systems: Suggested Changes to Truck & Motorcoach Regulations & Inspection Procedures*, U.S. Dept. Transportation (FMCSA), March 2013, findings based on data from Clean Vehicle & Education Foundation

# 135 CNG incidents characterized



Type of Incident	Number of Incidents	Percentage of Total (135)
Cylinder ruptures	50	37%
PRD release (no fire)	14	10%
Vehicle fire (no cylinder rupture)	17	13%
Accident w/another vehicle	12	9%
Single vehicle accident	6*	4%
Cylinder or fuel tank leak	14	10%
Other	7**	5%
Unknown cause	15+	11%

\*5 of these were at low underpasses

\*\* 5 related to operational/maintenance

+12 outside the U.S.

Source: *Natural Gas Systems: Suggested Changes to Truck & Motorcoach Regulations & Inspection Procedures*, U.S. Dept. Transportation (FMCSA), March 2013, findings based on data from Clean Vehicle & Education Foundation

# Many PRD-related incidents but many were not design-related or due to failures



- PRDs worked properly in 42% of incidents involving fire
- In half of these the gas ignited but was attributed to poor installation or PRD
- 35% of fires PRDs did not release but mostly because fire did not reach location of PRD so storage system was compromised
- Two-thirds of NGV accidents w/vehicles no gas was released.

*Natural Gas Systems: Suggested Changes to Truck & Motorcoach Regulations & Inspection Procedures*, U.S. Dept. Transportation (FMCSA), March 2013, findings based on data from Clean Vehicle & Education Foundation

# **(U.S.) Clean Vehicle Education Foundation has created specific stakeholder working groups to resolve these critical issues**

1. SANDIA Phase II modeling on indoor gas releases
2. Over pressure filling of CNG cylinders (short term) (related to temperature compensation at the fuelling station) Technical Bulletin has been published.
3. Over pressure filling of CNG Cylinders (mid term) will explore possible pressure control by the vehicle vs. the fuel dispenser
4. Cylinder valve issues – reliability – failure detection – safe removal – international labeling harmonization (best practices document to be produced)
5. Pressure activated PRD use and issues
6. PRD installation and venting

# Reality: CNG vehicles are safer than gasoline vehicles in tunnels.

- in 1989, several natural gas utilities and the New York State Energy Research and Development Authority jointly funded an comprehensive, \$1.2 million safety analysis of fuel-related accidents in tunnels.
- Conclusion: *modern tunnel environments, fanned by high-powered ventilation systems, would quickly remove and disperse gaseous fuels safely above ground in the event of an accident.*

# Reality: CNG vehicles are safer than gasoline vehicles in tunnels.

- Report done to overcome prohibitions of NGVs in tunnels in Boston, Massachusetts (1994)
- The comparison of the gasoline and CNG dispersion calculations demonstrates that ***the size of the flammable region from an incident involving a CNG fueled van is significantly smaller than the flammable region from a comparable incident involving a gasoline fueled van*** as long as the effective ventilation velocity is on the order of 0.10 m/s or higher.

Dispersion of CNG Fuel Releases in Naturally Ventilated Tunnels, Center for Fire Safety Studies, Worcester Polytechnic Institute, Mass., November 1994

# Reality: NGVs pose no risk in underground parking garages

- ***“A CNG vehicle poses no extraordinary risk in a typical parking garage; that is, the risk of the CNG vehicle is equal to or less than the risk posed by a gasoline fuelled vehicle.*** The conclusion is valid for both forced and natural circulation type garage designs and should cover every type of public parking garage normally encountered. ***Overall, parking in public garages is not a major CNG safety concern.***” (Caveat: Special cases, where the analysis cannot be extended, include a garage with no ventilation, or a garage with no ceiling registers [ventilation outlets]).

# Reality: Home fuelling appliances pose minimal risks in garages\*

The potential for a hazardous fire due to accidents (non-misuse failures) and even mis-use of the fuelling appliance are **1 in 10.7 million over one year.**



Source: *Safety Evaluation of the FuelMaker Home Refueling Concept*, Final Report, Waterland, Powars, and Stickles, National Renewable Energy Laboratory, NREL//SR540/36780, Golden, Colorado, February 2005.

\*Pertains only to Fuelmaker or devices with similar profiles.

# On the sea with LNG has some strong supporters...and for inland waterways

- "We support the steps taken to develop the use of liquefied natural gas (LNG) as fuel in European inland navigation because we are convinced of its advantages.
- The use of LNG by vessels into a transport system meets the highest level of security and fully meets the criteria of the CCNR on this point.  
**LNG-powered vessels are just as safe as others.**"

Hans van der Werf, Secretary General of the Central Commission for the Navigation of the Rhine (CCNR)

Source: <http://www.wk-transport-logistique.fr/actualites/detail/77917/l-europe-veut-developper-le-gnl-pour-la-navigation-interieure-.html#&panel1-1> 2014 09 10

Photo: © Dance



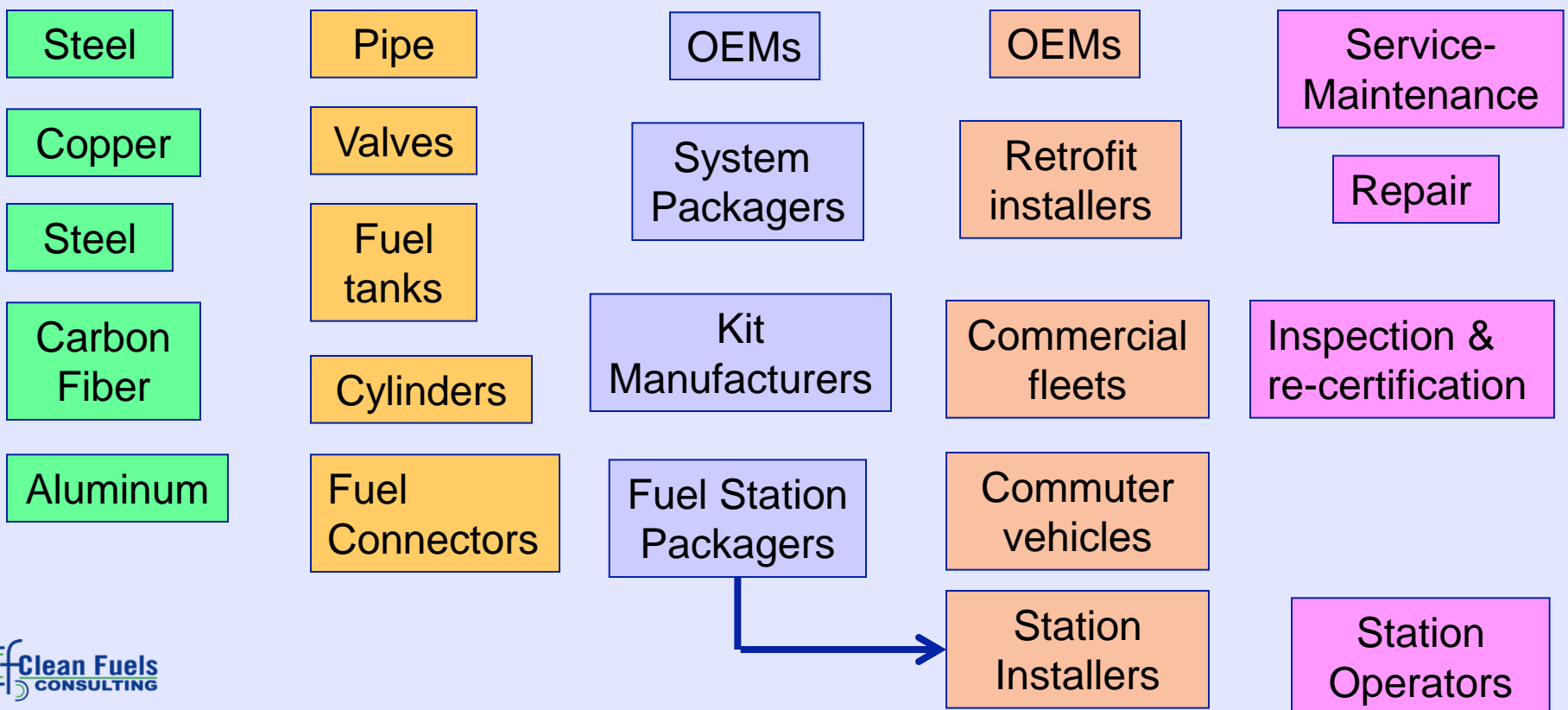
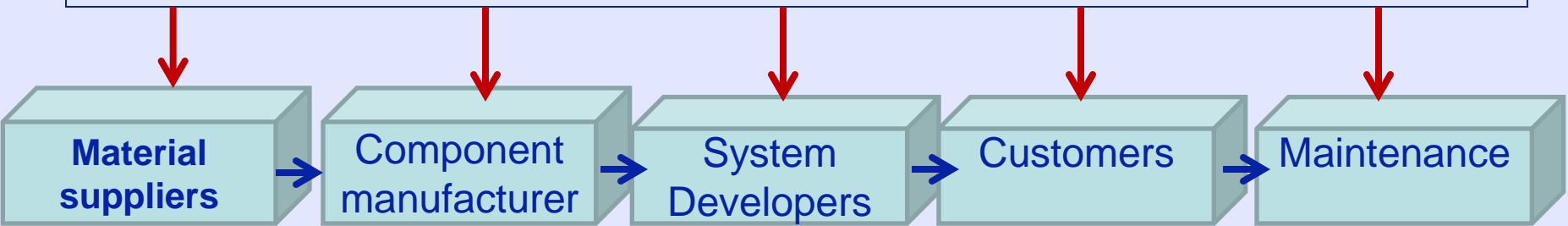
*Eiger-Nordwand is the first retrofitted LNG river container ship with funding from the EU Ten-T project. CO2 reduced by 40%; NOx & particulates by 90%*

# SAFETY in the NGV 'VALUE CHAIN'

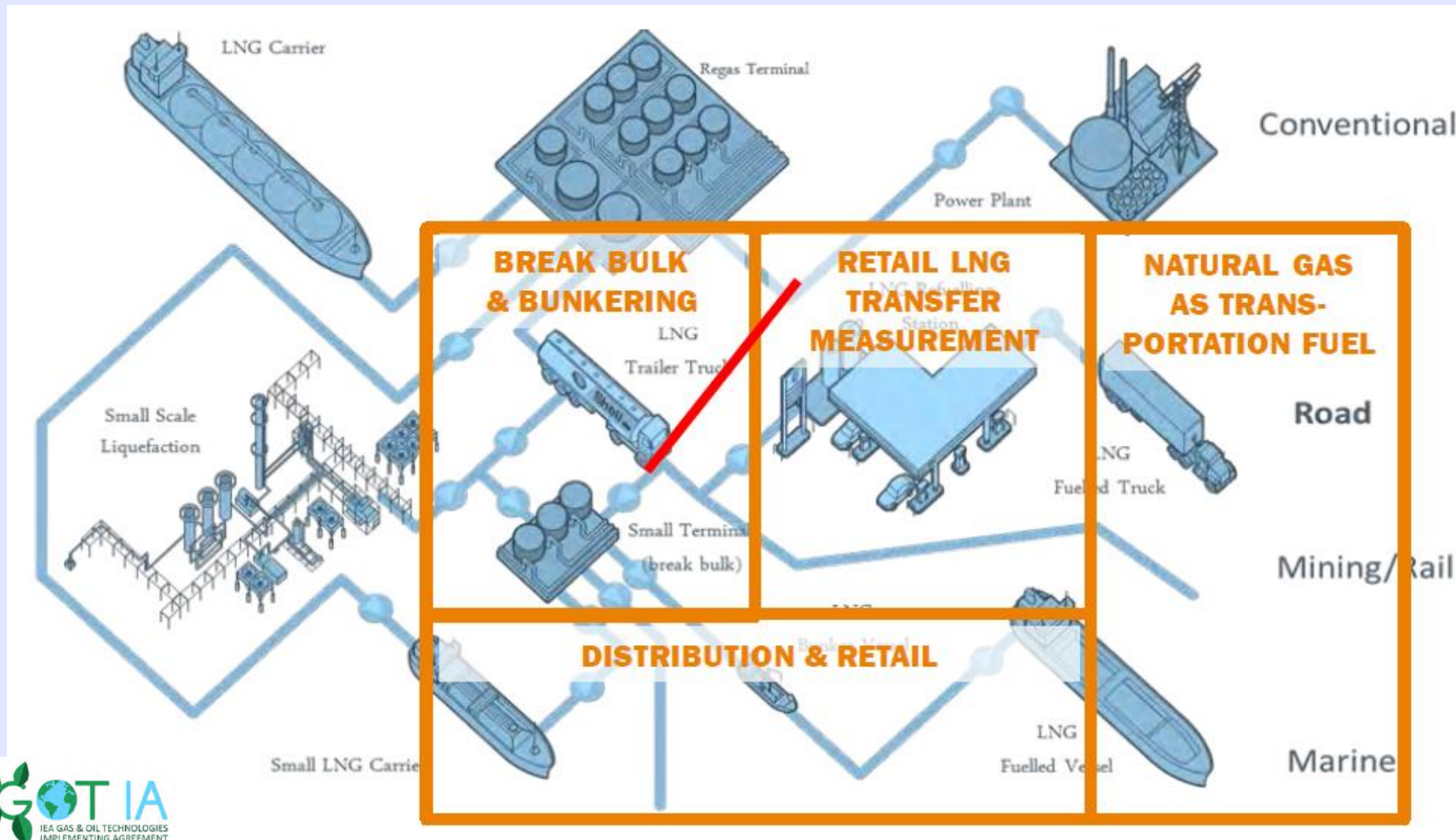
From 'mine-mouth' to tailpipe...and beyond



# Safety requirements are imposed along each link in the NGV value chain



# Small Scale LNG Value Chain



# Weak links along the Safety Chain

- Low quality raw materials
- Inferior components or 'knock-offs'
- Single unit certification – no batch testing
- Untrained certification officials
- Bribed certification officials
- Human errors

# Making weak links stronger

- Identifying the problem;
- Who is responsible? (buyer beware?);
- How to rectify the problem?
- What can be done to prevent a recurrence?
- Who is liable?
- Penalties?  
(enforcement)



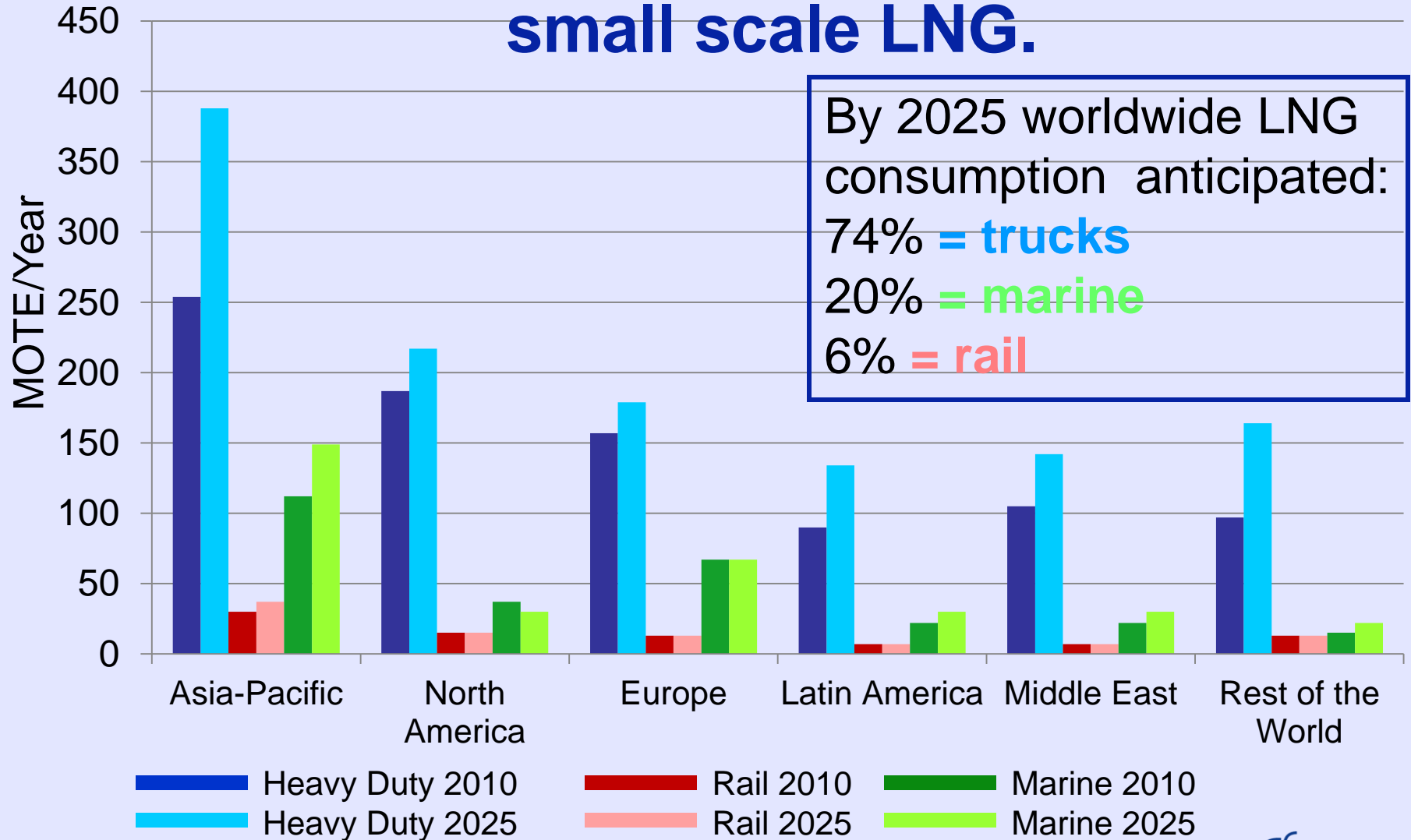
'He did it!' (Thomas Nast)

# Global NGV Safety

## Tying up the loose ends



# Overview of total energy consumption for transportation markets suitable for small scale LNG.



Source: Global Potential of Small Scale LNG Production, A quick scan study, TNO, 2014, report 10447.

Trucks, Rail and Maritime volumes are based on the estimations from the ExxonMobil graph, 2014

# More than 300 members from industries and associations are working together creating a global team

- NGVA Europe
- ANGVA – Asia/Pacific
- ARPEL – Latin America

**Regional  
NGVs  
Associations**

**NGV  
Global**

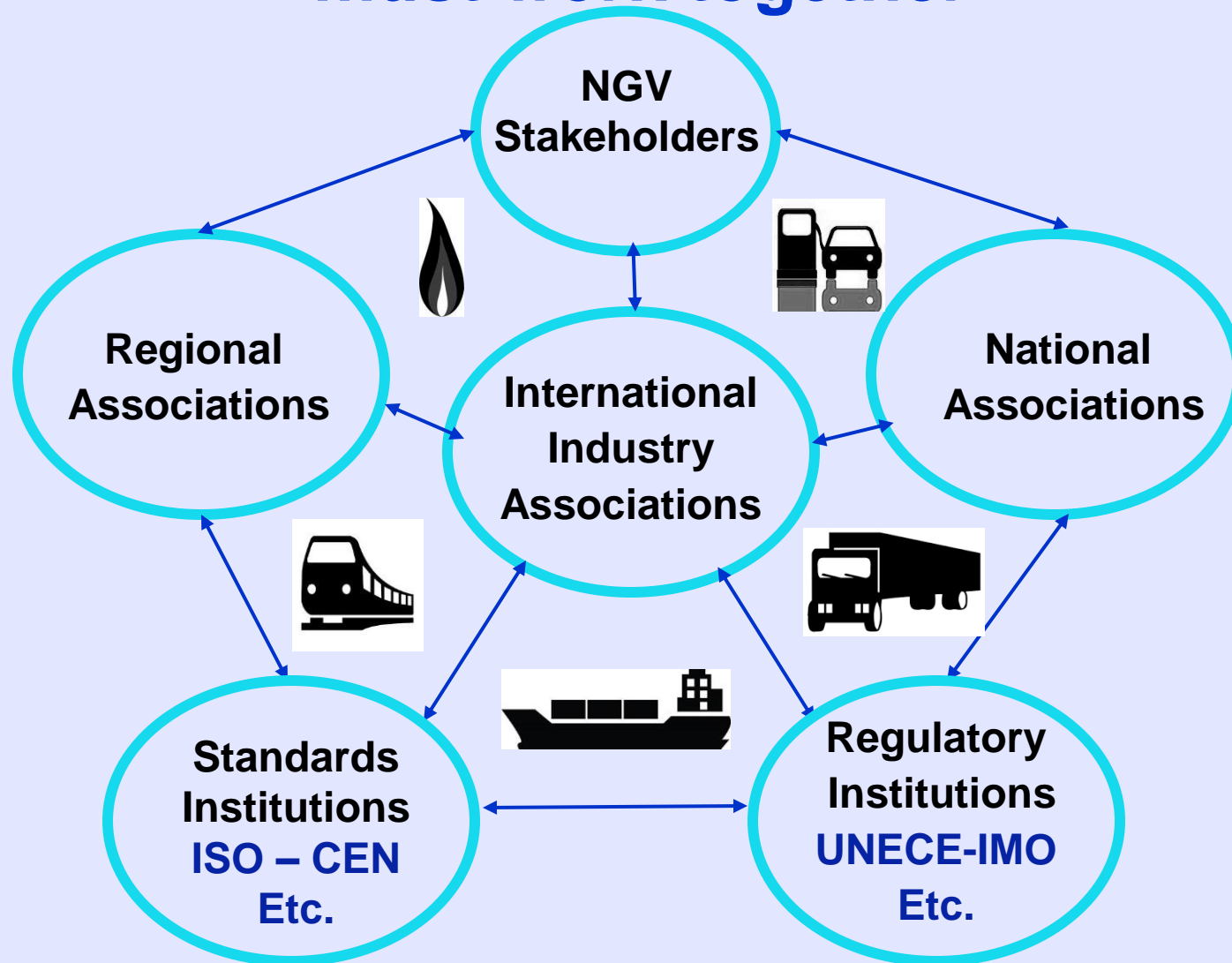


**The NGV  
Stakeholders**  
- Equipment &  
service suppliers  
- Energy  
industries  
- Vehicle-makers

**National  
NGVs  
Associations**

Argentina, Austria,  
Belgium, Bolivia,  
Brasil, Canada,  
Caribbean, China,  
Croatia,  
Cz.Republic,  
Denmark,  
Ecuador, Finland,  
France, Hungary,  
India, Indonesia,  
Italy, Japan,  
Malaysia,  
Netherlands,  
Norway, Pakistan,  
Portugal, Russia,  
South Korea,  
Spain, Sweden,  
Thailand, Turkey,  
Ukraine, USA,  
Uzbekistan

# Associations supporting gaseous fuel propulsion – *NGVs, marine, rail* -- must work together



# Strategic vision to promote safe technology & best practices (and, by the way, *market growth*)

- Cross-fertilized, harmonization of international standards and regulations that *recognize the common safety attributes* (and risks) of natural gas as fuel alternative to petroleum fuels (*to the best extent possible....*)
- Cross-fertilization of industry associations (road/off-road/marine/rail) and their members' knowledge, skills and experiences.
- Integration of NGV global markets for all applications – road/off-road, marine, & rail

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