Clean Cities Webinar
NGVs Past & Prologue
Lessons Learned to Create Deployment Strategies for Commercializing NGVs:
Global Overview of Markets & Poli-techs (standards & regulations)
presented by
Dr. Jeffrey Seisler
6 October 2014
Acknowledgements

• Thanks for the DOE for their support:
  - Clean Cities
  - International DOE
• Thanks to Marcy Rood-Werpy & Dan Santini for their personal support and enthusiasm for this work
• Special thanks to Dan Santini for his rigorous, dedicated and intellectually challenging involvement in refining this presentation.
Structure & Dynamics
Framework for this presentation

POLITICS

Poli-Techs
Standard & Regulations

TECHNOLOGY

IMPACT ON THE MARKET/STAKEHOLDERS

CUSTOMERS
Private/public fleets & commuters

BUSINESS
Equipment & Service Suppliers

FUEL SUPPLIERS
CNG/LNG/BioGas

Lessons Learned
Best Practices

REACTION IN THE MARKETPLACE

FEEDBACK

Lessons Learned
Best Practices
Overview of the Webinars

Webinar 1: 6 Oct 2014
• Background to success in NGV markets
  - *NGVs by the numbers:*
    *Looking Back-Looking Forward*
• Poli-techs: NGV Standards and Regulations

Webinar 2: Week of 17 November 2014
• NGV Technology, Best Strategies & Lessons Learned

Webinar 3: 15 December 2014
• Role of Government: *Policy making & Strategy Process*
• Infrastructure Concepts & Strategies
• Best Strategies: Institutional Lessons Learned
FACTORS REQUIRED FOR NGV SUCCESS

• Favorable economics
  – Cost differential between natural gas & petroleum;
  – Price differential of an NGV vs petrol/diesel vehicle
• Energy industry support
  – Gas industry vs. Oil/Gas industry
• Availability of vehicles (*real*, & not *implied* support of manufacturers)
• Government commitment
• Environmental policies driving lower emissions
New Fuel Reality Check

• Transition to new fuel(s) can affect our ability to compete in the world market.
• While it is tempting to make quick decisions, analysis is needed to make the best decisions.
• Technology breakthroughs and major world events may cause reevaluations.
• Transition will take years to complete.
• Even a wildly successful new fuel will coexist with gasoline and diesel for decades while older vehicles are phased out.

Source: Checklist for Transition to New Highway Fuel(s), Charles Risch, Danilo Santini, January 2012.
THE CRITICAL “NGV” STAKEHOLDERS
EACH ONE HAS A ROLE TO PLAY
(but the must be *motivated* to play!)
Balance of NGV Commercialization

NATURAL GAS INFRA-STRUCTURE

New diesel & petrol technologies

Fuel price

New diesel & petrol fuels

NGV CUSTOMER DEMAND

OEM PRODUCTION

Government

Government

Government
NGV success for customers is based on 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 $30,000-70,000+*
PRICE OF CRUDE OIL & NATURAL GAS

Natural gas typically tracks below oil but since 2009 the price is ‘decoupling’ (to the benefit of natural gas!)

Barrel of oil equivalent (bbl)
Ultimately it is the NGV running costs that make the difference…and natural gas generally is cheapest! BUT…fuel tax policies play an important role! (Italian example)

The energy cost of CNG is lower than alternatives.
NGVs by the numbers: Looking Back-Looking Forward

Source: ENGVA Conference theme/logo, Graz, Austria 2004
NGVs IN THE WORLD
2014

Data source: The GVR & ASIAN NGV, April 2014
The top 10 NGV countries in the world based on total NGVs
(with % price differential to petrol)

<table>
<thead>
<tr>
<th>Country</th>
<th>Total NGVs</th>
<th>Fuelling stations</th>
<th>% Price CNG less than Petrol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>3.500,000</td>
<td>1,904</td>
<td>75</td>
</tr>
<tr>
<td>China</td>
<td>3,000,000</td>
<td>5,730</td>
<td>50</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2,790,000</td>
<td>2,997</td>
<td>65</td>
</tr>
<tr>
<td>Argentina</td>
<td>2,359,673</td>
<td>1,932</td>
<td>71</td>
</tr>
<tr>
<td>Brazil</td>
<td>1,769,572</td>
<td>1,805</td>
<td>47</td>
</tr>
<tr>
<td>India</td>
<td>1,800,000</td>
<td>903</td>
<td>47</td>
</tr>
<tr>
<td>Italy</td>
<td>823,000</td>
<td>1,022</td>
<td>62</td>
</tr>
<tr>
<td>Colombia</td>
<td>476,506</td>
<td>703</td>
<td>47</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>450,000</td>
<td>213</td>
<td>74</td>
</tr>
<tr>
<td>Thailand</td>
<td>441,182</td>
<td>491</td>
<td>75</td>
</tr>
</tbody>
</table>

Data source: The GVR, April 2014

• US$/Liter vs 1 Nm3 gas
The top 10 NGV countries in the world & vehicles per station

<table>
<thead>
<tr>
<th>Country</th>
<th>Total NGVs</th>
<th>Fuelling stations</th>
<th>Vehicles per fuelling station</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>3,500,000</td>
<td>1,904</td>
<td>1,838</td>
</tr>
<tr>
<td>China</td>
<td>3,000,000</td>
<td>5,730</td>
<td>524</td>
</tr>
<tr>
<td>Pakistan</td>
<td>2,790,000</td>
<td>2,997</td>
<td>931</td>
</tr>
<tr>
<td>Argentina</td>
<td>2,359,673</td>
<td>1,932</td>
<td>1,221</td>
</tr>
<tr>
<td>Brazil</td>
<td>1,769,572</td>
<td>1,805</td>
<td>980</td>
</tr>
<tr>
<td>India</td>
<td>1,800,000</td>
<td>903</td>
<td>1,993</td>
</tr>
<tr>
<td>Italy</td>
<td>823,000</td>
<td>1,022</td>
<td>805</td>
</tr>
<tr>
<td>Colombia</td>
<td>476,506</td>
<td>703</td>
<td>678</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>450,000</td>
<td>213</td>
<td>2,113</td>
</tr>
<tr>
<td>Thailand</td>
<td>441,182</td>
<td>491</td>
<td>899</td>
</tr>
</tbody>
</table>

Data source: The GVR, April 2014
Europe Total NGVs
~ 1,354,316
Refuelling Stations
~ 4,108
Stations Under Construction 292

April 2014

Vehicles per fuelling station
(600-1000 vehicles per station economically is optimal)

* Rounded up figures

Data source: The GVR, April 2014
### Top Ten NGV Countries in the World

#### % NGVs of All Vehicles

<table>
<thead>
<tr>
<th>Country</th>
<th>Total NGVs</th>
<th>Total vehicle population&lt;sup&gt;1&lt;/sup&gt;</th>
<th>% NGVs of All Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>3.500.000</td>
<td>11.900.000</td>
<td>3</td>
</tr>
<tr>
<td>China</td>
<td>3.000.000</td>
<td>109.220.000</td>
<td>3</td>
</tr>
<tr>
<td><strong>Pakistan</strong></td>
<td>2.790.000</td>
<td>2.636.000</td>
<td><strong>106</strong></td>
</tr>
<tr>
<td>Argentina</td>
<td>2.359.673</td>
<td>11.473.000</td>
<td>21</td>
</tr>
<tr>
<td>Brazil</td>
<td>1.769.572</td>
<td>37.271.000</td>
<td>5</td>
</tr>
<tr>
<td>India</td>
<td>1.800.000</td>
<td>22.622.000</td>
<td>8</td>
</tr>
<tr>
<td>Italy</td>
<td>823.000</td>
<td>42.000.000</td>
<td>2</td>
</tr>
<tr>
<td>Colombia</td>
<td>476.506</td>
<td>3.812.000</td>
<td>13</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>450.000</td>
<td>1.634.600**</td>
<td>28</td>
</tr>
<tr>
<td>Thailand</td>
<td>441.182</td>
<td>12.749.000</td>
<td>4</td>
</tr>
</tbody>
</table>

* A vast majority of vehicles are Tuk-Tuks not autos. Auto population numbers subject to availability and very wide variation

** 2010 data

<sup>1</sup>International Assoc Automobile Constructers (OICA), 2013 (2012 data)

Data source: The GVR, April 2014
### Top ten NGV countries in the world by vehicles per capita

<table>
<thead>
<tr>
<th>Country</th>
<th>Total human population*</th>
<th>NGVs</th>
<th>NGVs per 1000 people</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armenia</td>
<td>3,017,400</td>
<td>244,000</td>
<td>80,86</td>
</tr>
<tr>
<td>Argentina</td>
<td>42,669,500</td>
<td>2,359,673</td>
<td>55,30</td>
</tr>
<tr>
<td>Iran</td>
<td>77,381,000</td>
<td>3,500,000</td>
<td>45,23</td>
</tr>
<tr>
<td>Bolivia</td>
<td>10,027,254</td>
<td>273,342</td>
<td>27,25</td>
</tr>
<tr>
<td>Georgia</td>
<td>4,483,800</td>
<td>80,600</td>
<td>17,97</td>
</tr>
<tr>
<td>Pakistan</td>
<td>186,262,000</td>
<td>2,790,000</td>
<td>14,97</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>30,183,400</td>
<td>450,000</td>
<td>14,90</td>
</tr>
<tr>
<td>Italy</td>
<td>60,021,955</td>
<td>823,000</td>
<td>13,71</td>
</tr>
<tr>
<td>Colombia</td>
<td>47,561,000</td>
<td>476,506</td>
<td>10,01</td>
</tr>
<tr>
<td>Brazil</td>
<td>201,032,714</td>
<td>1,769,572</td>
<td>8,80</td>
</tr>
</tbody>
</table>

*Data source: The GVR, April 2014*

*United Nation 2013*
Europe Total NGVs
~1.354.316
NGVs Refuelling Stations
~ 4.108

April 2014

* Rounded up figures

Data source: The GVR, April 2014
Total Fuelling Stations (Public and Private)

Europe Total NGVs

~ 1,354,316

Refuelling Stations

~4,108

Stations Under Construction

292

April 2014

* Rounded up figures

Data source:
The GVR, April 2014
# NGV Growth Rates 2006-2014

(April 2014)

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2014</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>World</strong></td>
<td>4,6 Million</td>
<td>19,6 Million</td>
<td>326%</td>
</tr>
<tr>
<td><strong>China</strong></td>
<td>97,200</td>
<td>3 Million</td>
<td>2986%</td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>1 Million</td>
<td>1,77 Million</td>
<td>77%</td>
</tr>
<tr>
<td><strong>Europe</strong></td>
<td>556,000</td>
<td>1,35 Million</td>
<td>143%</td>
</tr>
<tr>
<td><strong>Ukraine</strong></td>
<td>67,000</td>
<td>170,000</td>
<td>153%</td>
</tr>
<tr>
<td><strong>Italy</strong></td>
<td>382,000</td>
<td>823,000</td>
<td>115%</td>
</tr>
</tbody>
</table>

Data: The GVR, April 2014
World NGV Growth

Vehicle Numbers & % Growth Rate

Data source: The GVR, April 2014
World Fuelling Station Growth
Station Numbers & % Growth Rate

Data source: The GVR, April 2014

# Fuelling Stations

<table>
<thead>
<tr>
<th>Year</th>
<th>Station Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>5,482</td>
</tr>
<tr>
<td>2003</td>
<td>6,666</td>
</tr>
<tr>
<td>2004</td>
<td>7,842</td>
</tr>
<tr>
<td>2005</td>
<td>10,647</td>
</tr>
<tr>
<td>2006</td>
<td>12,219</td>
</tr>
<tr>
<td>2007</td>
<td>13,038</td>
</tr>
<tr>
<td>2008</td>
<td>14,169</td>
</tr>
<tr>
<td>2009</td>
<td>16,278</td>
</tr>
<tr>
<td>2010</td>
<td>20,681</td>
</tr>
<tr>
<td>2011</td>
<td>21,503</td>
</tr>
<tr>
<td>2012</td>
<td>25,135</td>
</tr>
</tbody>
</table>

%/yr

- 22% growth
- 18% growth
- 16% growth
- 17% growth
- 15% growth
- 15% growth
- 12% growth
- 17% growth
- 4% growth
- 5% growth
- 10% growth
- 15% growth
- 20% growth
- 25% growth

Data source: The GVR, April 2014
World Wide NGV Growth Actual & Various Projections to 2020

1991 to 2005 actual annual sales growth of 17.6%

2006 to 2020 projected annual sales growth of 17.8%

- 10,000,000
- 20,000,000
- 30,000,000
- 40,000,000
- 50,000,000
- 60,000,000
- 70,000,000

Int’l Gas Union SG5.3 (2009)

Pike Research (2011)

Navigant Research (2013)

John Lyon, IANGV, 2007 adapted by Clean Fuels Consulting 2013
Projected global regional sales volume outlook

Forecast NGV registrations by segment U.S. & Canada 2012-2023

Registrations

Source: N. American Light Duty Vehicles & Medium/Heavy Duty Truck Forecasts (prepared for the Fuels Institute), Navigant Research, August 16, 2013.
How good are projections?
A U.S. NGV historical perspective…
growth based on provisions in the
Clean Air Act Amendments of 1990

Source: Gas Research Institute circa 1991
Standards & Regulations

• A foundation for commercializing technologies
• Complex international networks
• Harmonization is the end-goal
• To be successful implementation AND enforcement are critical
DEFINITIONS

• STANDARDS
  – Not ‘legal’ (i.e. not binding) but are intended to be *defacto* models for codes
  – Performance or prescriptive

• REGULATIONS (also known as *codes*)
  – *Dejure*/legal, with enforcement implications
  – Can adopt standards by reference or amendment
Critical Need for Standards & Regulations

• Safety of equipment: fabrication & testing
• Reliability of equipment & systems
• Promote best practices
• *Harmonized* standards & regulations foster economic *(not cheap)* critical mass for equipment sold across international markets.
• No regulations – no markets

= ACCOUNTABILITY  = PROFIT
LEVELS OF STANDARDS & REGULATIONS
(The Patchwork Quilt)

**REGULATIONS**

1. International Bodies
   - Global
   - Regional (EC)
   - Countries

2. National Standards Institutions

3. Specialty Standards Organisations
   - Cylinders
   - Meters
   - NGOs & Associations

**STANDARDS**

1. United Nations
   - International Standards Organization (ISO)
   - Committee for European Normalization (CEN)

**Private Sector Participants**

E X P E R T S
UN Structure for Gaseous Fuel Vehicle Regulations

United Nations Economic Commission for Europe (UN / ECE)

Inland Transport Committee

World Forum for Harmonization of Vehicle Regulations

Working Party.29

Group of Experts on General Safety Provisions (GRSG)

Regulation 110

Group of Experts on Pollution and Energy (GRPE)

Regulation 115

Informal Group Gaseous Fuelled Vehicles

HDDF TF

LNG TF

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:
I. LPG RETROFIT SYSTEMS
II. CNG RETROFIT SYSTEMS

Road Signage

CNG

LNG

Group of Experts on
General Safety
Provisions (GRSG)

Regulation 110

Specific Components of CNG Systems and Their Installation on Vehicles (R67 is corollary for LPG)
UNECE regulation development process can take a minimum of 15 months; often longer.
ISO STANDARDS FOR NGVs

ISO International Organization Standardization

TC220
Cryogenic vessels
(Working Groups 1,2,3)

TC193
Natural Gas Characteristics

TC22
Road Vehicles

TC58
CNG cylinders

ISO 15500 (1-20)
ISO 15501 (1-2)
ISO 14469.1 M1/N1
ISO 14469.2 M2/N2
ISO 14469.3 250 bar
ISO 11439
ISO 19078
ISO 12617 LNG connector
ISO 12614 LNG components
ISO 15500 (1-20)
ISO 15501 (1-2)

ISO took over the responsibility to develop fuelling station standards from CEN.

The final ‘Draft International Stage’ for stations & Vehicular Refuelling Appliances (VRAs) (prEN 13638) is adopted (March 2014) and should be finalized shortly.

THE TYPICAL ISO STANDARDS DEVELOPMENT PROCESS TAKES 3-4 YEARS

Year 1: March
New Work Item Proposed

Year 1: June
Working Draft Prepared

Year 2: June
Committee Draft Prepared

Year 3: June
Draft International Standard (DIS) (Enquiry)

Year 3: Dec.
Final DIS Approval

Year 4: June
ISO Publishes Standard

ISO

Clean Fuels Consulting
U.S. Department of Energy
Regulatory Landscape to Develop Engine & Emissions Certification Regulations

Heavy Duty Vehicles

European Commission
- DG Enterprise/Industry
  - Motor Vehicle Emissions Group (MVEG)
    - Light Duty
    - Heavy Duty
      - Euro II
      - Euro III
      - Euro IV
      - Euro V (Links to R.115)
      - Euro VI
  - Euro V Links to R.115

UN / ECE
- Inland Transport Committee
  - WP29
    - GRPE
      - Informal Group Gaseous Fuel Vehicles (GFV)
      - OEM-Related
      - Retrofit
        - R 85 Power Measurement
        - R 49 Emissions HDVs
        - R.115 CNG/LPG Systems, Emissions & Safety
      - R-115 CNG Components & installation
      - R-67 LPG Components & installation
      - LNG TASK FORCE L-NGVs

Delegation of work to GRSG
UNECE Regulations for heavy duty LNG trucks and for dual-fuel engines are in place!

- **LNG trucks** amending R.110 (NGV components) come into force by June-July 2014.
- **OEM heavy duty dual-fuel Euro VI** (R.49, Emissions of HD engines) in force as of July 2013;
- **HDDF Euro V** will come into force July 2014.
- **Dual-fuel retrofit** engine regulations are now in development (new regulation).
Changes in International Maritime Organization (IMO) regulations is the next door opener to the largest potential NGV market of the future.
IMO limits on NOx emissions and sulphur limits in fuel has begun the shift to LNG in the marine sector.

NOx emissions reductions from engines

% Sulphur reductions in fuel

New emissions limits and sulphur content limits take effect in U.S. and European Emission Control Areas (ECAs).
Various LNG Bunkering Solutions… but standards & regulations are needed

1. Terminal Tank to Vessel
2. Truck to Vessel
3. Vessel to Vessel

Alternative: Portable Tank Transfer

Source: Bunkering of Liquefied Natural Gas-fueled Marine Vessels in North America, American Bureau of Shipping, 2014
LNG for shipping will be good for LNG trucking as fuel supply is integrated between sea and land applications.
Safety continues to be a critical issue for regulators and customers

• “What is known is liked. What is unknown is disliked. Make the unknown known.”
• Industry must understand the reasons for failures and fix the problems.
• Scientific studies (i.e. HAZOP, etc.) are needed.
• Videos help educate people
• Training at all levels is critical
Selected Summary Points

- Alternative fuel source(s) must be pursued on a timely basis as any major transition will take many years.
- Fuel transition(s) must be as few as possible, because the infrastructure change-over expense may will be huge.
- Realignment of ongoing fuel shifts may be necessitated by major changes in:
  - Technology
  - International affairs
  - World pricing and supply of fuels

Source: Checklist for Transition to New Highway Fuel(s), Charles Risch, Danilo Santini, January 2012.
Lessons Learned

Create & support NGV associations

• NGV associations have been lightning rods and catalysts for NGV growth
• Associations provide a focus for advocacy work (especially national), market strategy & development and technology advancement.
• Stakeholders need to continue and expand their support of the associations as it elevates the commercialization efforts.
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
METHANE IS A DIVERSE & FLEXIBLE FUEL FOR THE TRANSPORT SECTOR
Keep your eyes focused on the road ahead and make good policy today that gets us where we want to go!

The future is a big place. It’s going to take a long time to get there.
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