The 20% Sweet Spot

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The Hythane Company LLC

12 Minutes To Discuss:

- What is Hythane®?
- Evolution of our fuel blend from a historical perspective based on demonstration projects and independent studies.
- Analysis that brought us to the “sweet spot”.

Hythane® Defined

- Natural gas has long been regarded as the bridge technology to the hydrogen future, and Hythane®is the bridge technology between natural gas and hydrogen.
- Hythane®is a patented mixture of natural gas and hydrogen, between 5 and 7 percent hydrogen by energy or 80% natural gas / 20% hydrogen by volume
- Invented in 1989 by Frank Lynch & Roger Marmaro of HCI (Hydrogen Consultants, Inc.)

Hydrogen Powered Car UCLA 1972

Rear of car is full of 400 bar tanks

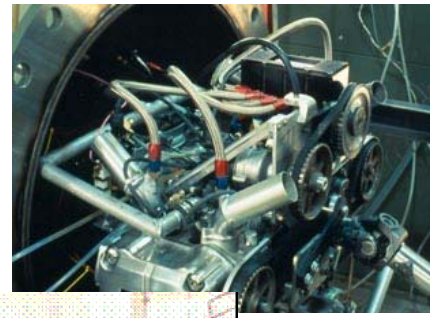
Range = 115 km

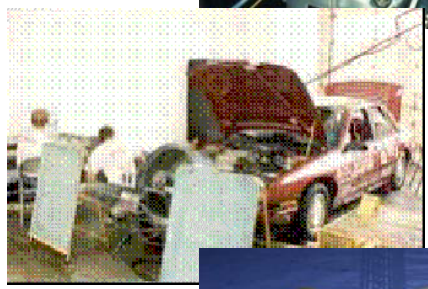
"World's First" H_2 Projects

- First Liquid H_2 Car (1974)
  Tank fills half the trunk - range = 200 km
- First Forklift (1979 & 1980)
  Metal Hydride fuel storage and counterweight
- Mitsubishi Mini-Truck & Bus (1981)
  Compressed gas and metal hydride fuel storage
- Mining Vehicle (1984)
  Metal Hydride fuel storage

More H_2 Projects

- Closed-Cycle Submarine Engine (1992)
  NAVSEA, CVI injection, chemical hydride fuel storage
- Methanol with Hydrogen Cold Start (1993)
  NREL, On-board H_2 from methanol decomposition
- Portable Fuel Cell Power Supply (1994)
  DARPA, Ball, Ballard, various H_2 sources
- Ford Ranger (4) HICE trucks (1995)
  SCAQMD, Xerox, West Hollywood





Still More H_2 Projects

- HICE Hybrid Bus (1996)
  DOE, Westinghouse/Savannah River, City of Savannah, Georgia Tech Research Institute, 1996 Summer Olympics (Atlanta), metal hydride storage

- Mercedes Sprinter Vans (6) (1999)
  Hamburg Hydrogen Association, compressed gas storage

- Cummins Generator Sets (2) (2002)
  AZ Public Service, Stuart Energy

H_2 Refueling Station Projects

- 1 of 3 Ballard buses operated in Chicago in 1997-1998. Frank Lynch built the dispensing system and operator interface, wrote the manuals and did the operator training. Air Products was the customer.
- Another H2 station, similar to the Chicago project, for Ford. This was completed in 1999.

Leverage Leads To Sweet Spot

How do we exploit the most benefit from hydrogen for the least cost?

Challenge

- H_2 is 4X the cost of diesel and 5X the cost of natural gas
- Storage issues due to gas density also creates range problems

Positive

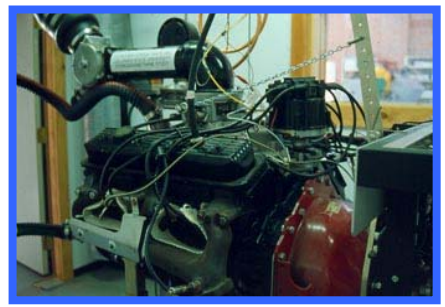
- Extremely low or no emissions
- High efficiency ICEs are possible, at lower cost than fuel cells (today)

Hythane® Projects

- Hythane® S-10 (1991)
  HCI, tri-fuel (gasoline, CNG, Hythane)

- Denver Hythane® Project (1992)
  DOE Clean Cities

- First Hythane® parametric study (1992)
  DOE/NREL, testing at Colorado State University
  0-30% Hydrogen Testing



- Montreal Hythane® Project buses (2) (1995)
  HydroQuebec, Cummins 10L

More Hythane® Projects

- SunLine Transit Buses (4) (2003)
  DOE/NREL, Cummins Westport 5.9L

- Hythane® Station (2004)
  TransFort, Fort Collins, CO

- First Hythane® Engine for China (2) (2005)
  Hythane Company, Yuchai 7.9L

- First Hythane® Engine for India (2) (2006)
  Hythane Company, Ashok Leyland 6.0L

Independent Validation

SunLine Hythane® Bus Project (2003) Concludes With The Same Findings As All Other Studies

- First engine manufacturer involvement in Hythane®(Cummins-Westport)
- 20-32% hydrogen by volume
- Best emissions reduction to date (50% NOx decrease with 7% hydrogen energy [20% by volume])

Fiddle With The Fuel Blend

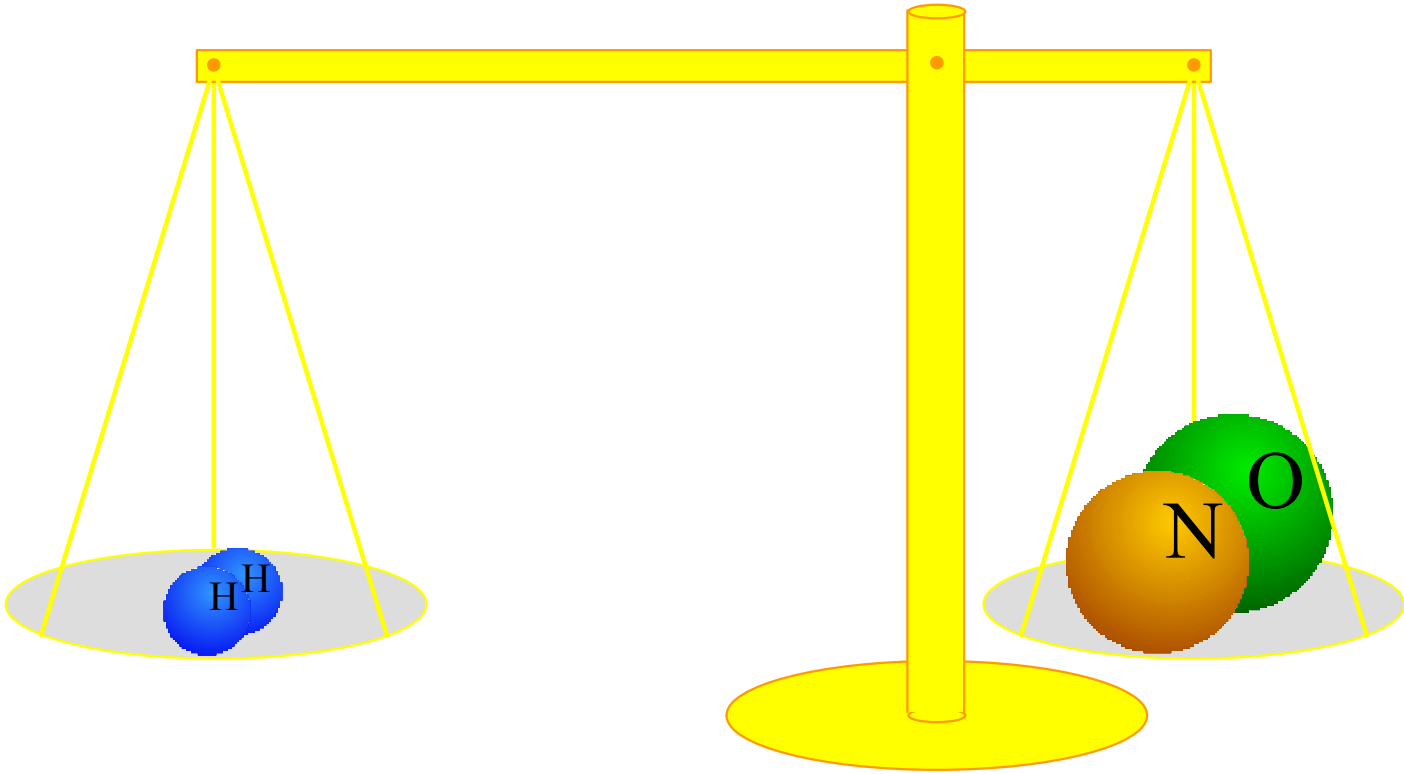
There are 3 interdependent parameters in adjusting a lean burn CNG engine for Hythane. We can:

- Reduce NOx
- Reduce Non-Methane Hydrocarbons
- Increase Efficiency

Tweaking one of these variables affects the other two. Take one to the maximum benefit or make compromises.

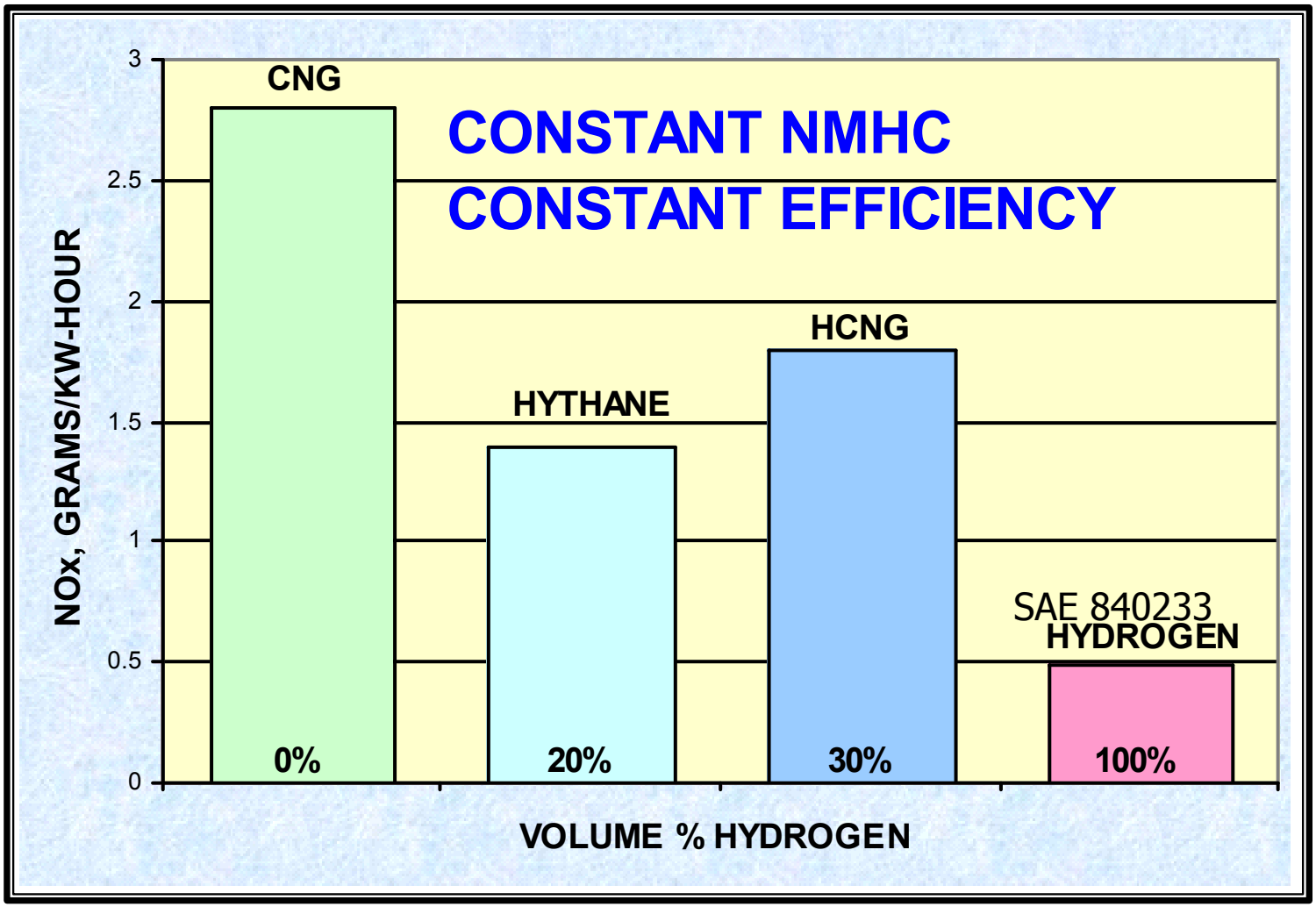
The US Hythane® strategy for reducing urban smog is "Reduce NOx as much as possible without making NMHC or efficiency worse than CNG".

Hythane® Leverage



Most Cost-effective Use of H_2

Is More Hydrogen Better?

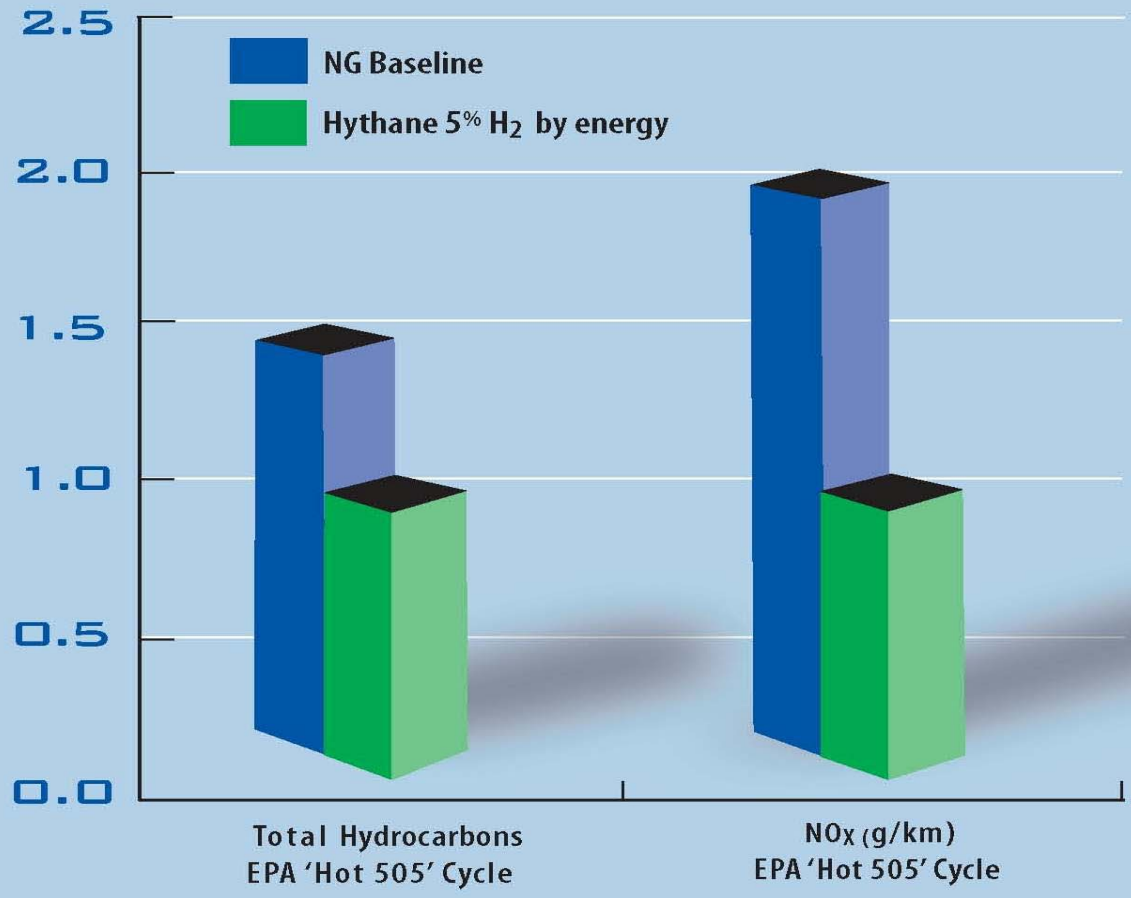


Data from Montreal Hythane Project

1993 GM 5.7L TBI Denver Hythane Project

EPA 'Hot 505' Vehicle Transient Cycle Composite Results

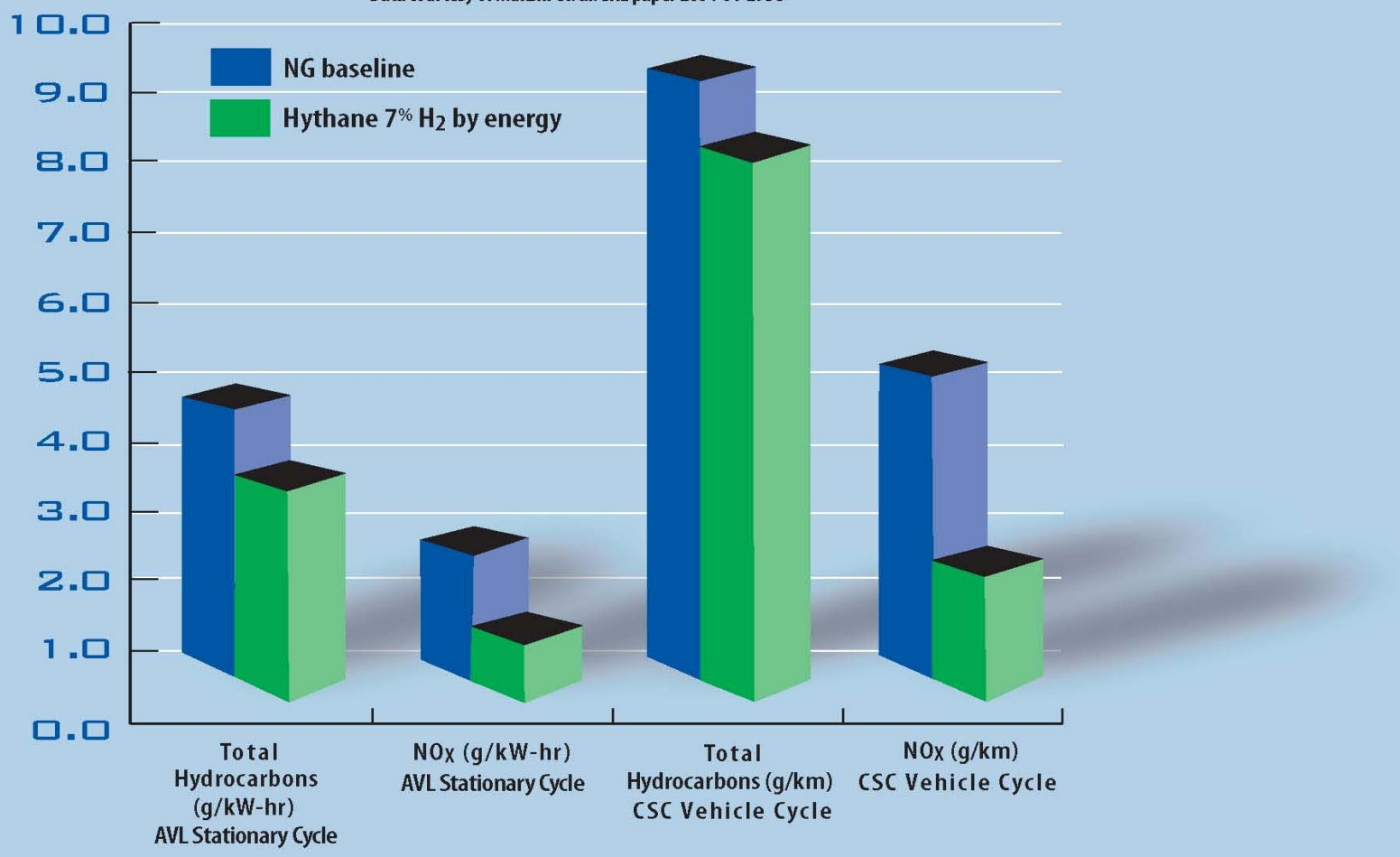
Data courtesy of Hydrogen Components, Inc.

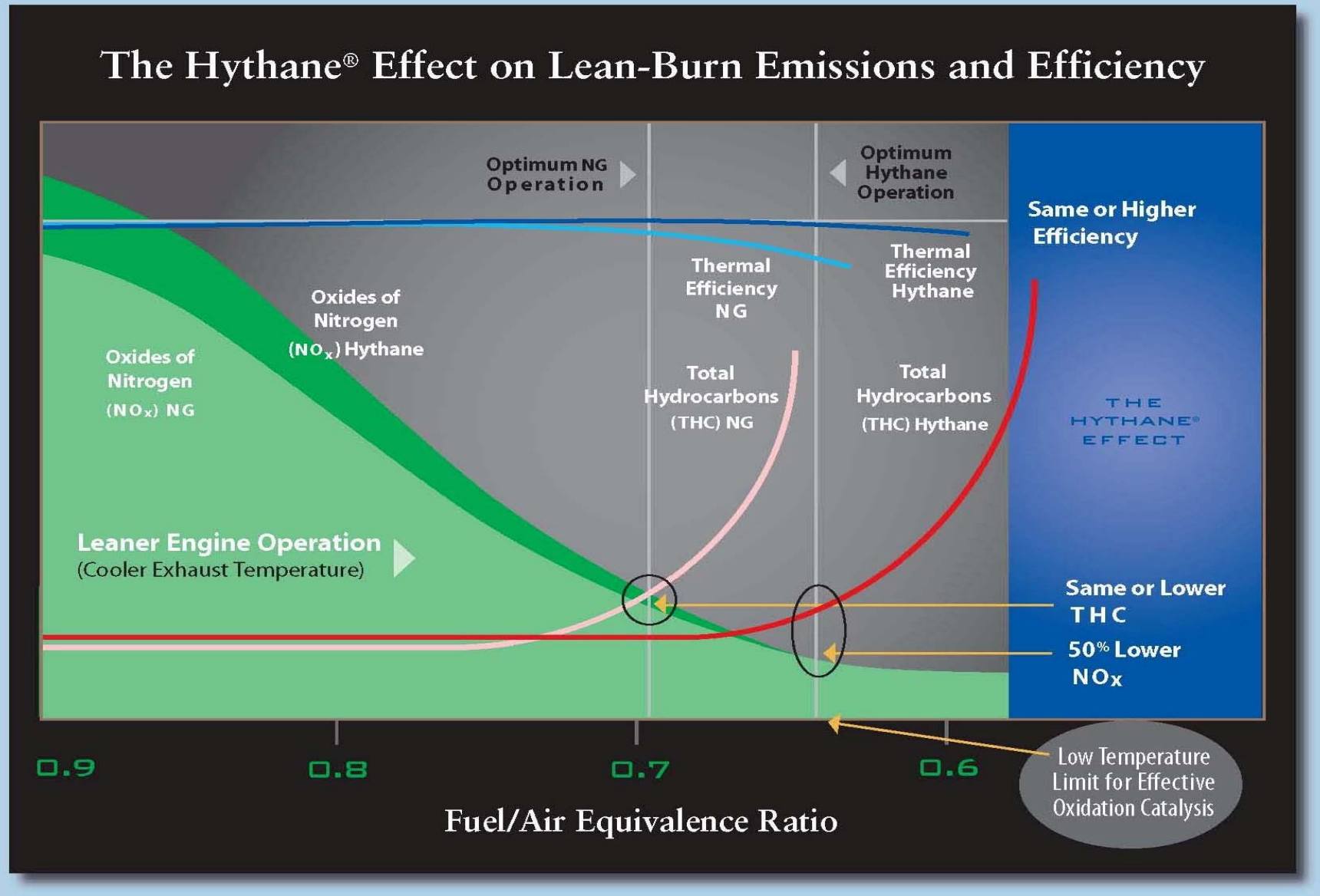


2004 Cummins Westport B Gas Plus

AVL Stationary and CSC Vehicle Transient Cycle Composite Results

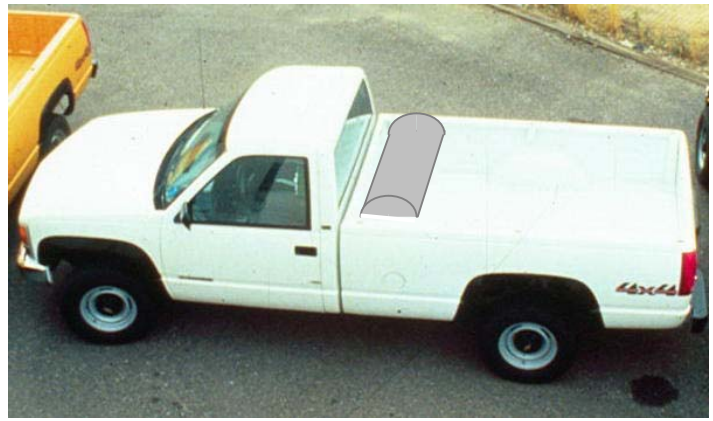
Data courtesy of Munshi et. al. SAE paper 2004-01-2956



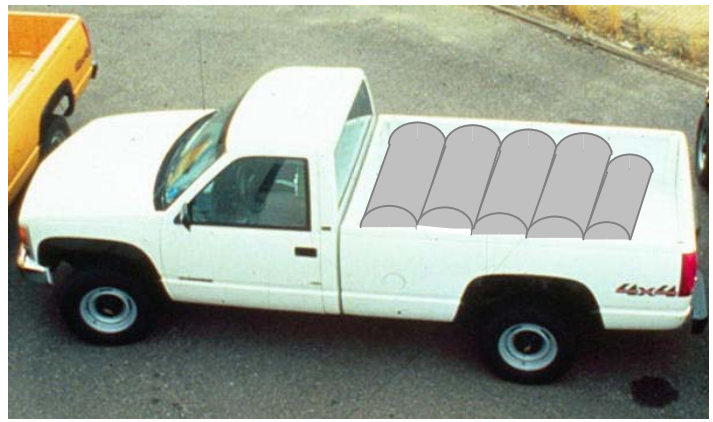

The Hythane® Effect on Lean-Burn Emissions and Efficiency
Optimum NG Operation
Optimum Hythane Operation
Same or Higher Efficiency
Thermal Efficiency NG
Thermal Efficiency Hythane
Oxides of Nitrogen (NOx) Hythane
Oxides of Nitrogen (NOx) NG
Total Hydrocarbons (THC) NG
Total Hydrocarbons (THC) Hythane
THE HYTHANE® EFFECT
Leaner Engine Operation
(Cooler Exhaust Temperature)
Same or Lower THC
50% Lower NOx
0.9
0.8
0.7
0.6
Low Temperature Limit for Effective Oxidation Catalysis
Fuel/Air Equivalence Ratio

Effect of Hydrogen on Tank Volume

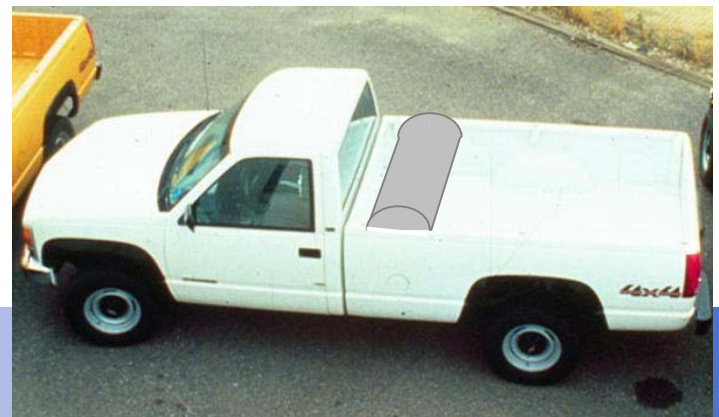
CNG, 300 km
H_2,<70 km in same tank



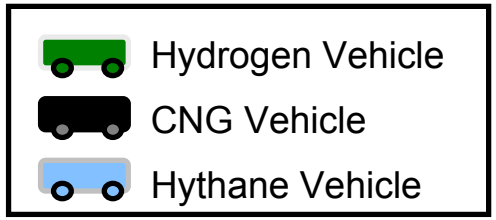
H_2, 300 km
4.5 times more volume



Hythane, 300 km
1.2 times more volume



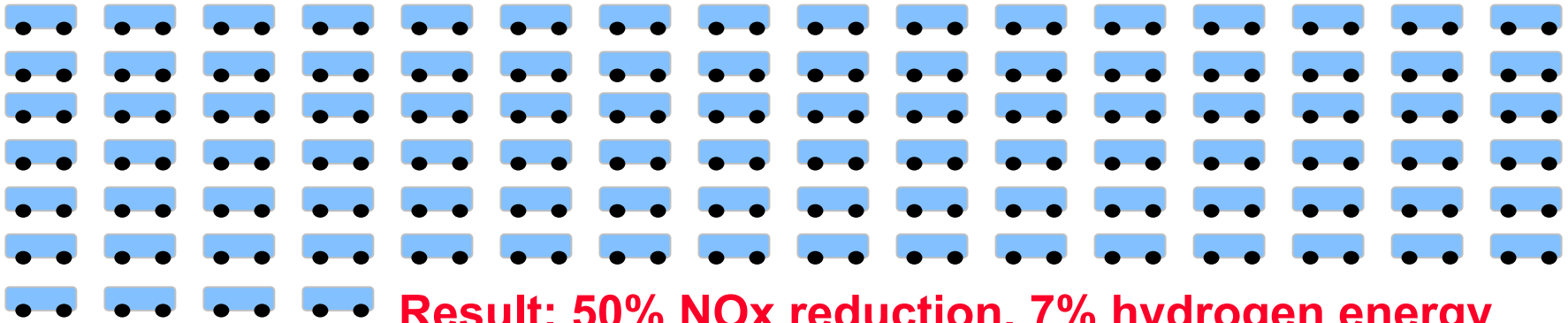
What is the best use of 7% Hydrogen Energy?



Case 1: Convert 7 CNG Vehicles to Hydrogen

Result: 7% NOx reduction, 7% hydrogen energy

Case 2: Convert 100 CNG Vehicles to Hythane®



Result: 50% NOx reduction, 7% hydrogen energy

Hythane® – The Transition Fuel

- ✓ Proven technology
- ✓ Most cost effective use of Hydrogen that is available today
- ✓ Piggybacks on existing CNG/NG infrastructure / It builds on and co-exists with natural gas stations
- ✓ Up to 50% NOx emission reductions
- ✓ Provides tremendous strategic flexibility: Can be calibrated to reduce NOx by up to 30% without decrease in range or increase range up to 10% with no decrease in NOx
- ✓ Reduces emissions of greenhouse gases by 7%
- ✓ Roll out of Hythane® infrastructure (NG reformation & blending) most cost effective 1st step toward hydrogen infrastructure development
- ✓ Clean H_2-enriched NG fuel is available **TODAY!**

Conclusion

- Hythane® is the fuel
- Hythane® is the calibration
- Hythane® is our collective expertise and experiences

Thank you for your time.

Questions?

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