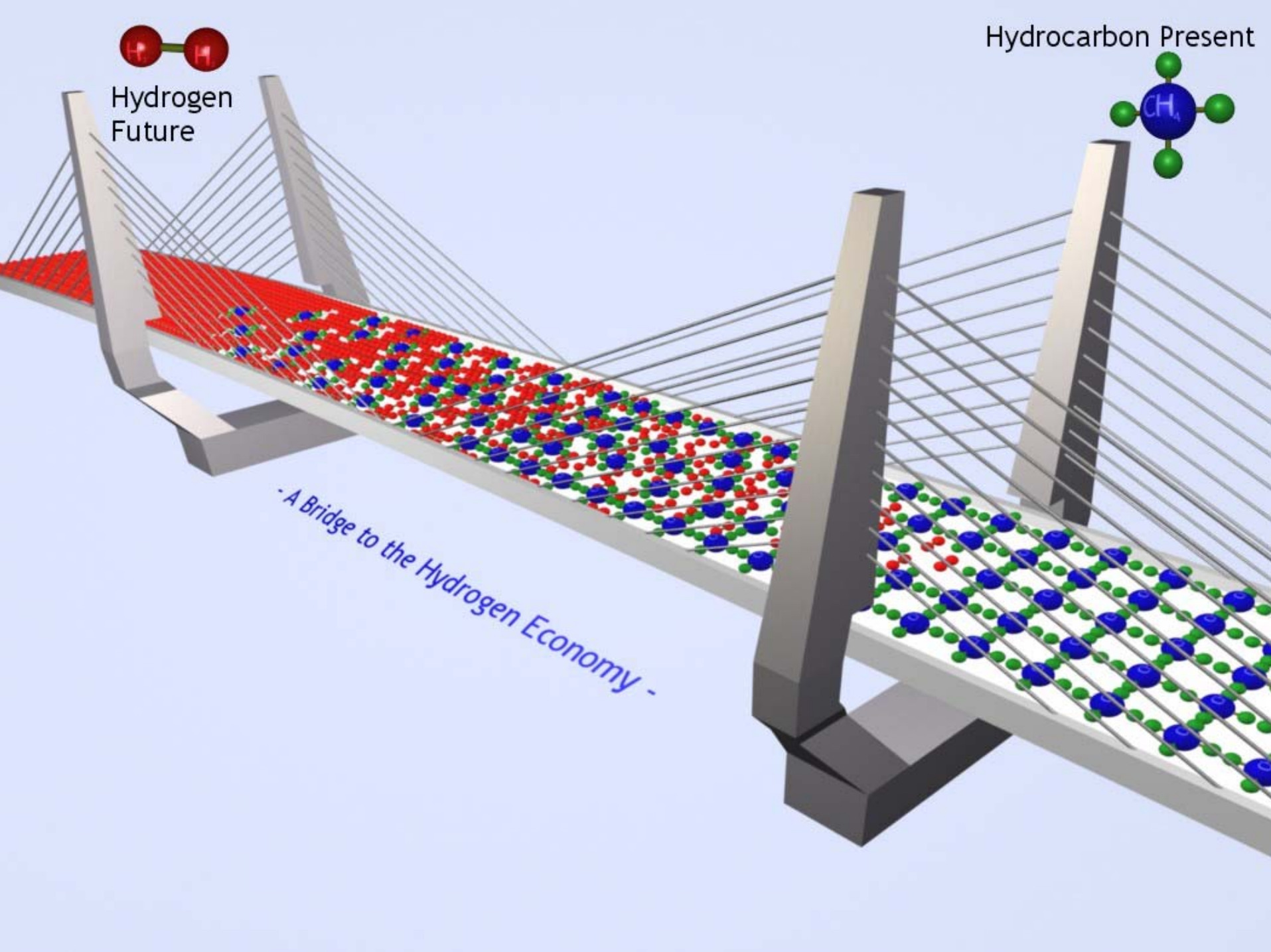
From Hydrocarbons to Hydrogen

John Webb

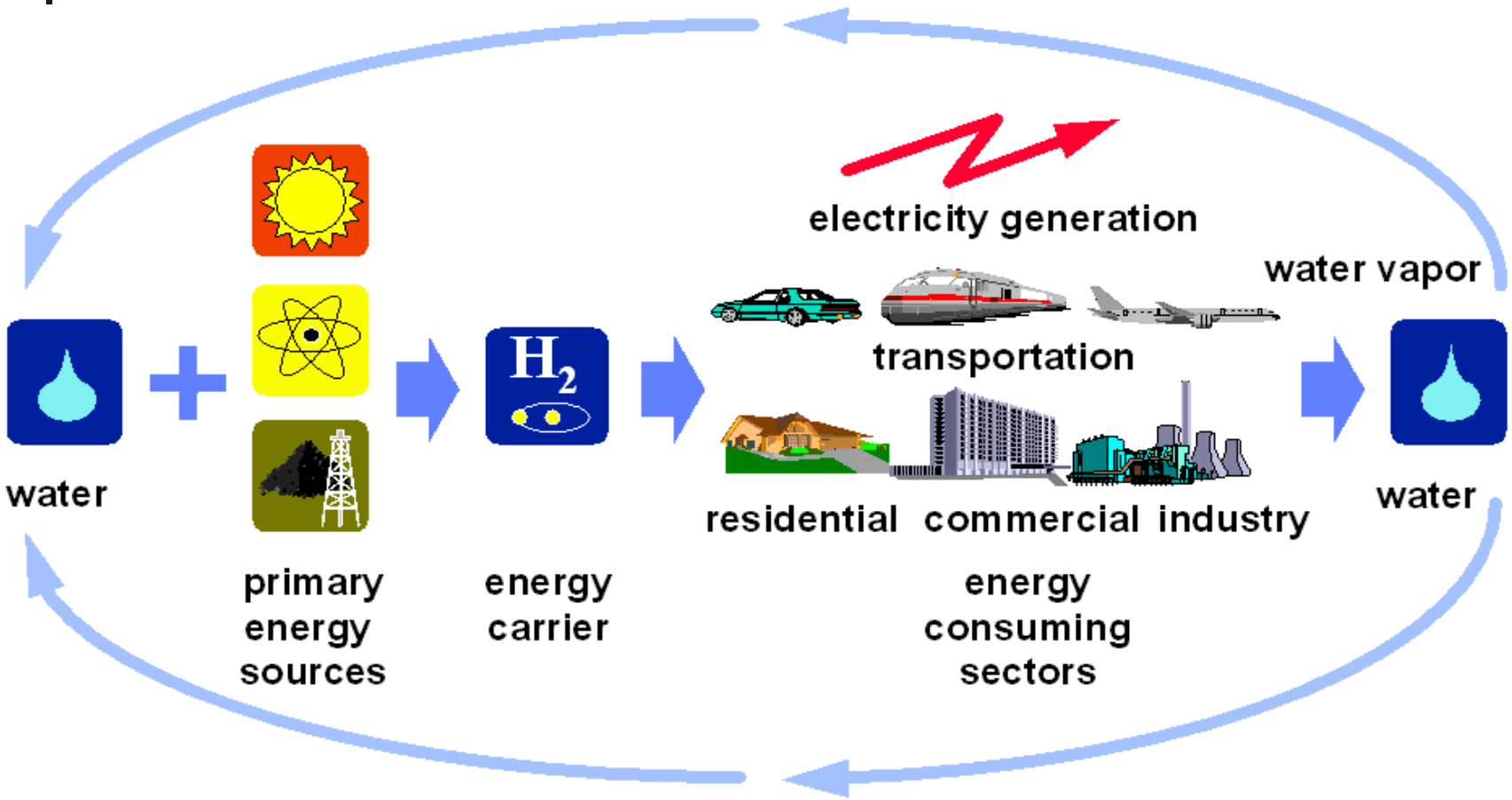
ASRA Retreat – June 2002


Hydrogen
Future
Hydrocarbon Present
- A Bridge to the Hydrogen Economy -

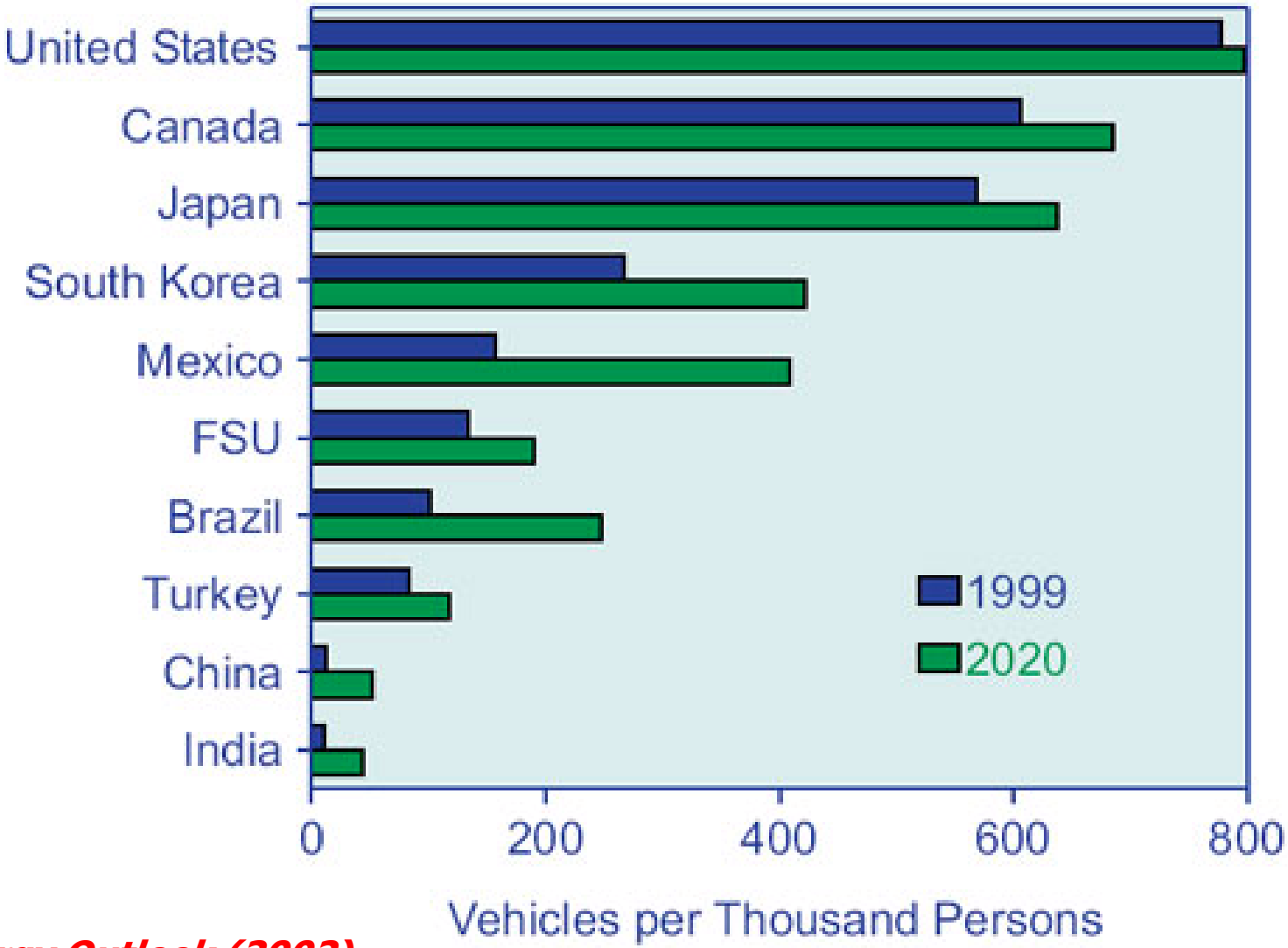
“ . . .the cost of producing [gasoline] is far beyond the financial capacity of private industry... In addition the development of this new power may displace the use of horses, which would wreck our agriculture."

- U.S. Congressional Record 1875

Hydrogen as an Energy Carrier



Worldwide growth in Vehicle Use



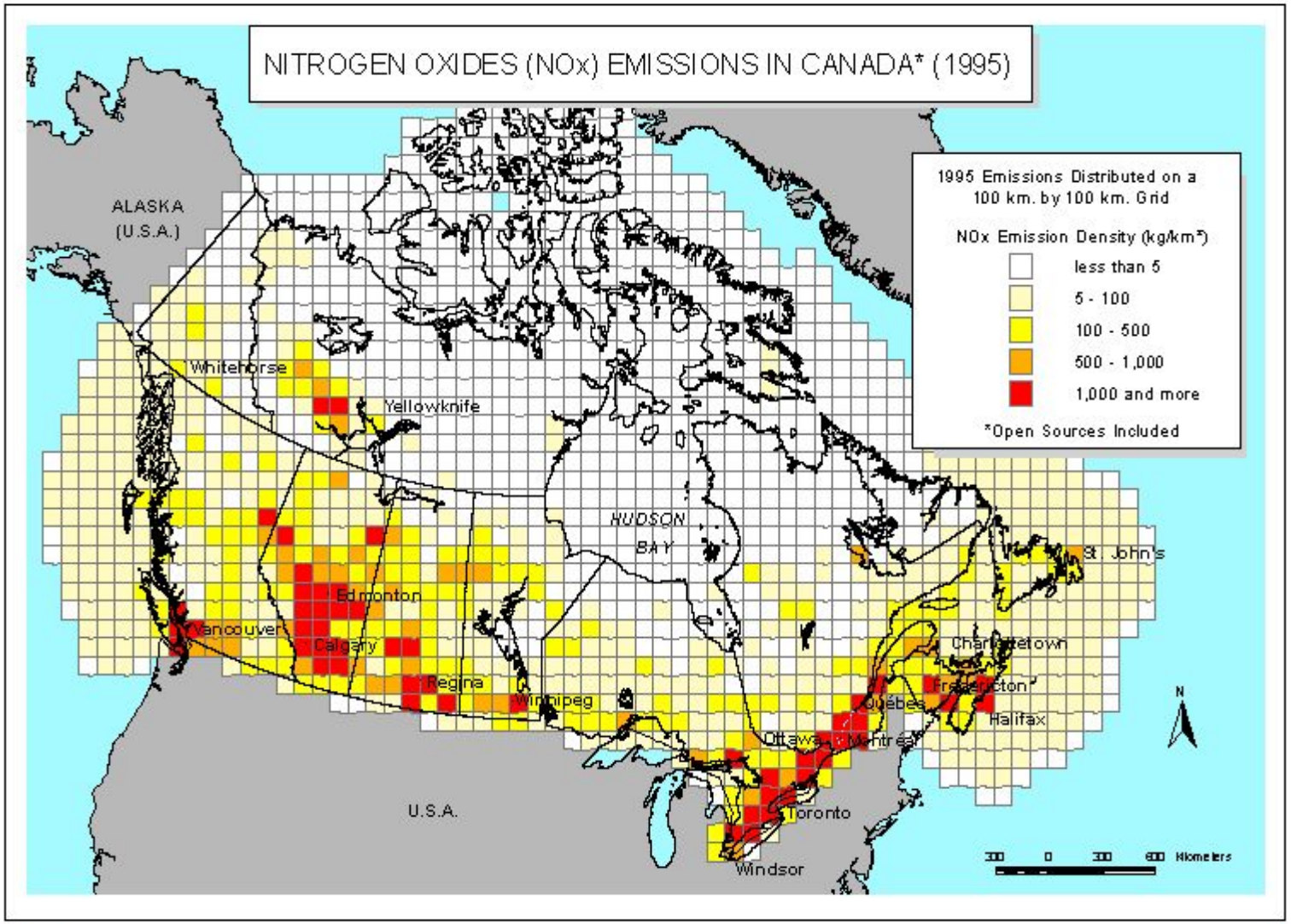
EIA, Energy Outlook (2002)

Growing Incentives and Drivers for Alternative Fuels

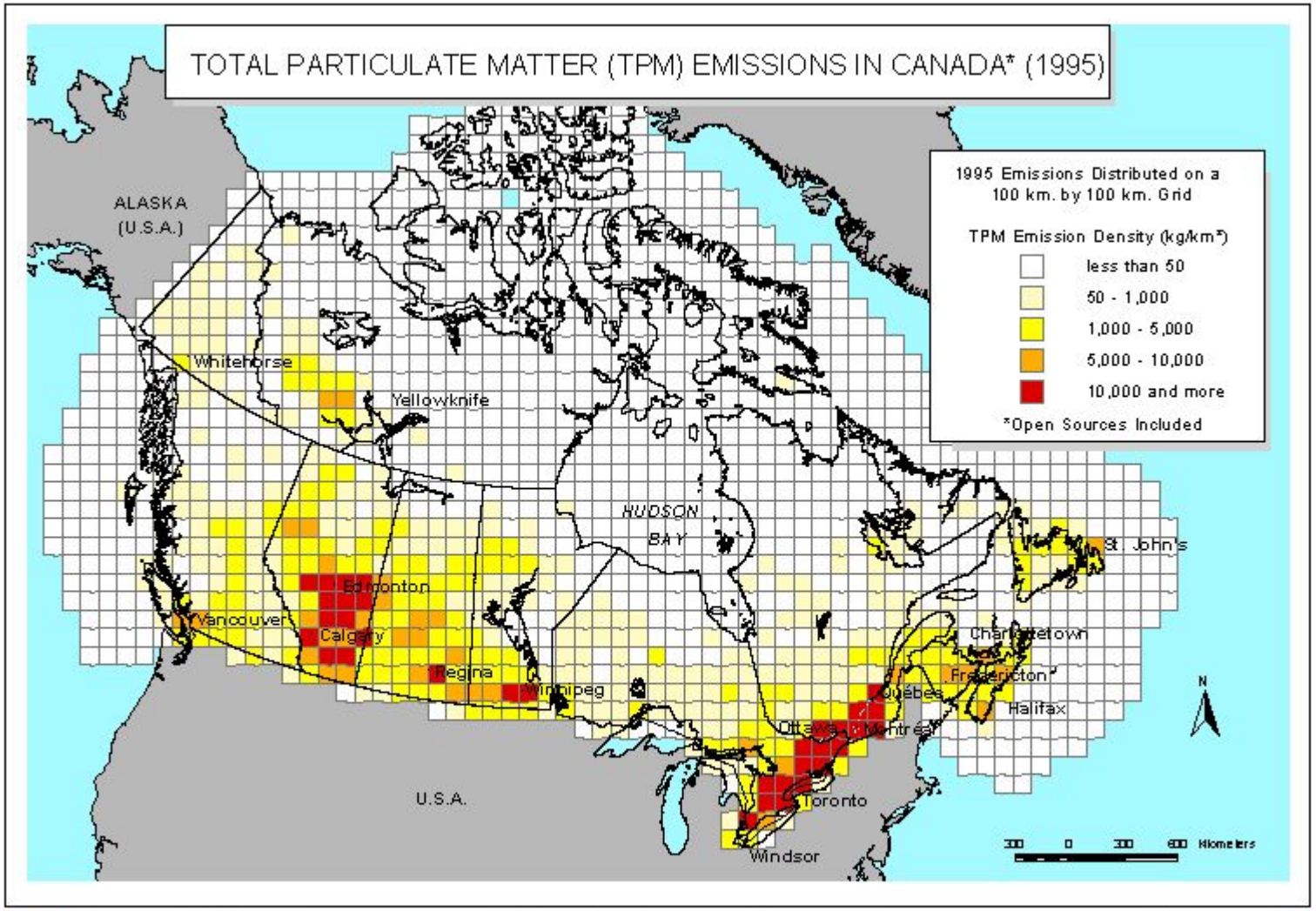
Examples

- EU -15 countries: 20% alternative fuels by 2020
  - half to be met by natural gas
  - Market size: 23M NGVs => U$10B market potential
- US – Energy Tax Incentives Act of 2002
  - US$2.2B in tax credits for Alternative Fuels
  - NGV growth forecast for US - 10% annually
- Policy shift to NGV- Iran, India, Australia
- Kyoto – EU to ratify, US – own emissions plan

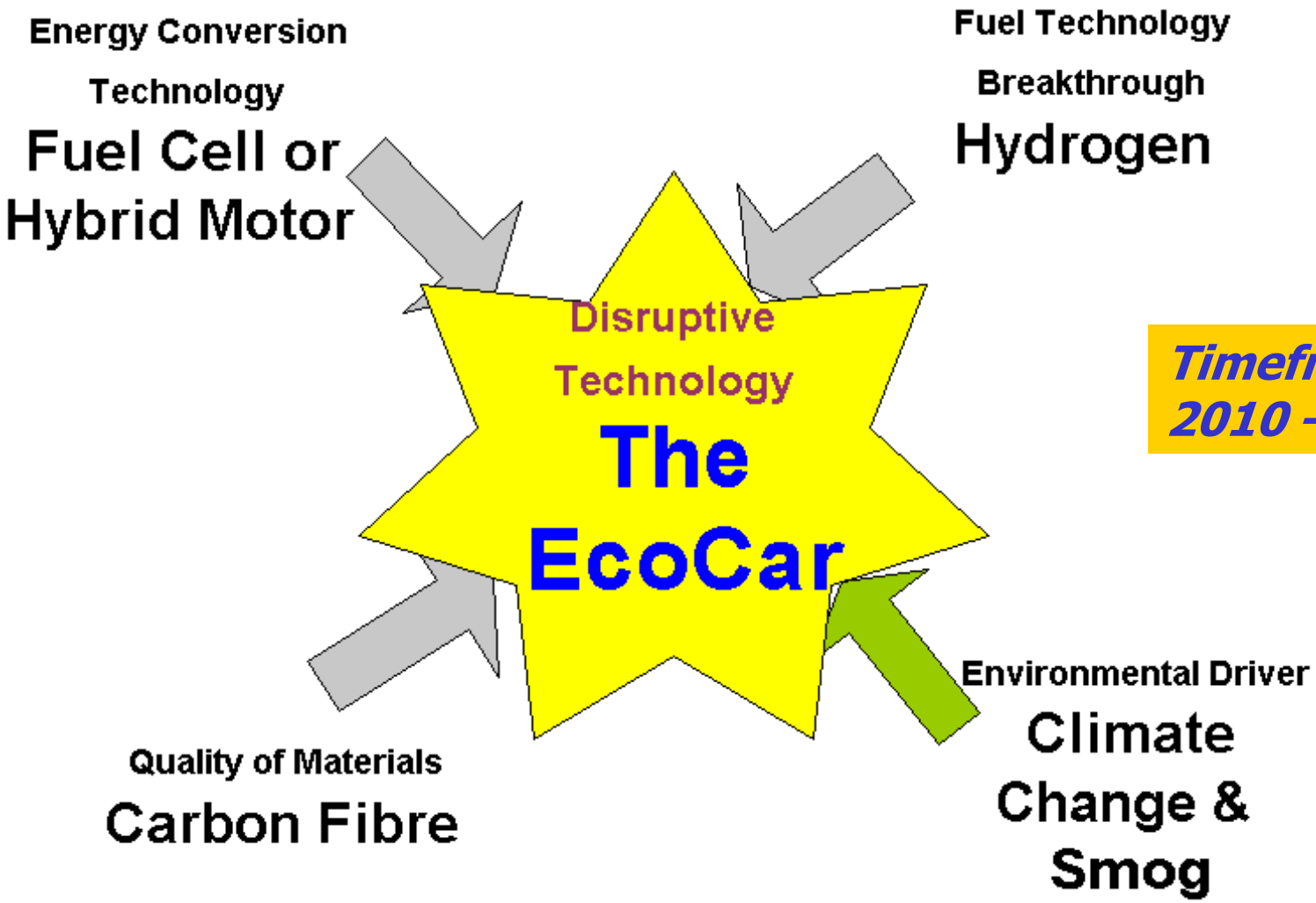
Turning Red to Green



Turning Red to Green



Step change will occur upon convergence of:



Timeframe 2010 –2020?

Courtesy of Bob Mitchell, AENV

fuel cells are conversion systems for hydrogen

- Still a developing technology not yet commercial
- Solid oxide fuel cells well suited for power generation
- Synthesis gas can be used directly – integration with coal, refinery bottoms and biomass.
- High conversion efficiency (fuel $\rightarrow$ electricity)
  - ~50% efficient
- 50% "waste" heat appears at high temperatures
  - "Waste" heat can be efficiently used
- Alberta well placed with Global ThermoElectric solid oxide fuel cell development.

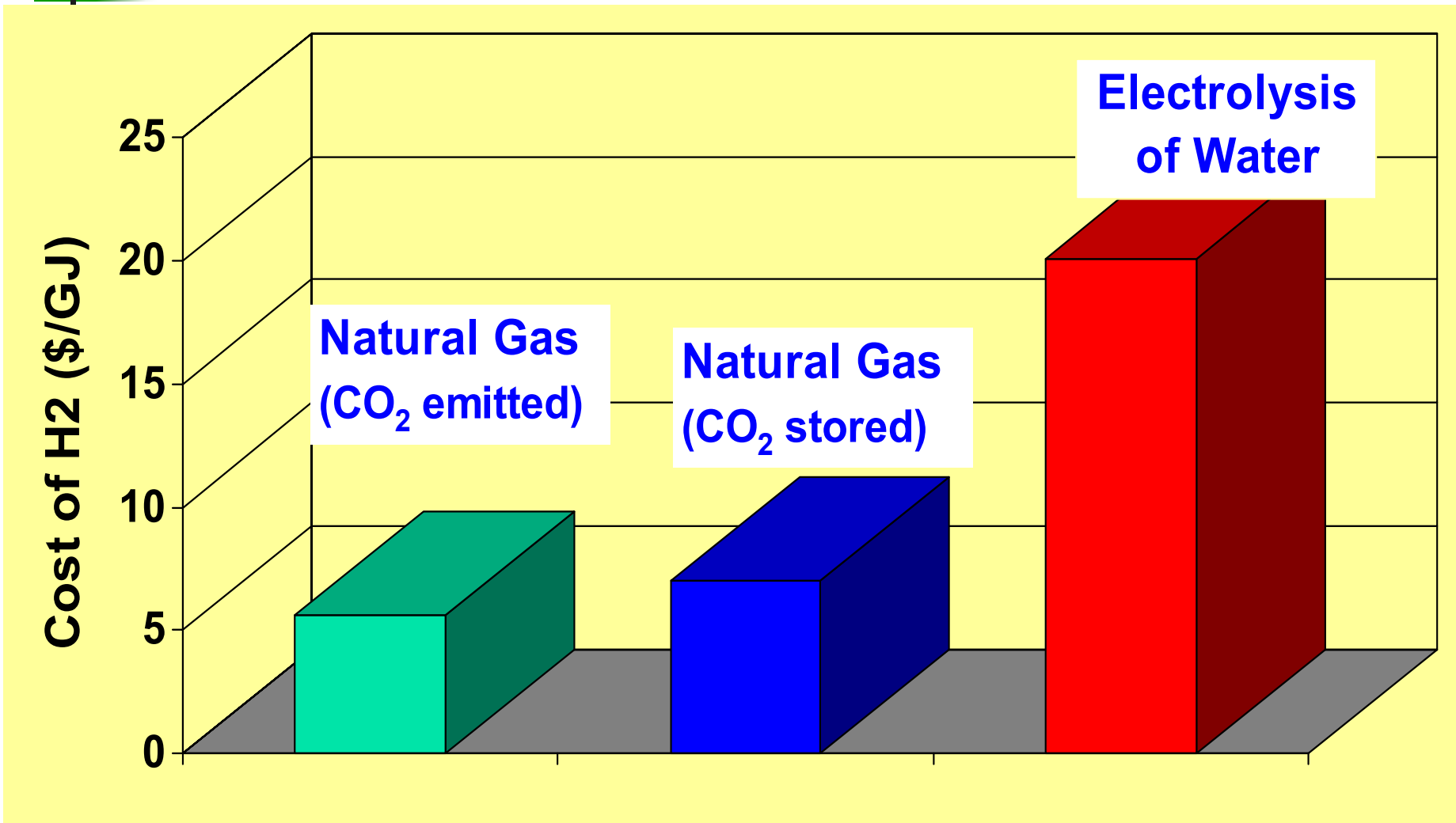
Fuel Cell Application - What is the fuel?

- Replace Combustion Engine
  - Gasoline (Arthur D. Little Co.) - 2x fuel economy much reduced pollution
  - Natural gas
  - Methanol, ethanol, dimethyl ether - all from natural gas
  - H_2 - from natural gas or electricity
  - Metal hydrides - not likely for mass production
- Integrated power and heat
  - Natural gas
  - propane

Worldwide Hydrogen Production

Raw Material	H_2 Production
Natural gas	48%
Oil	30%
Coal	18%
Water (electrolysis)	4%

Economics favor production from hydrocarbons with carbon storage



IEA Greenhouse Gas Program (Kelly Thambimuthu)

Model

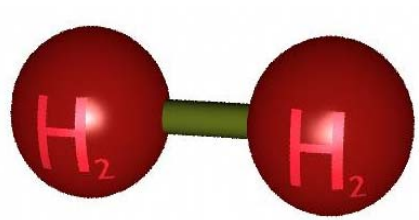
- INDUSTRY, GOVERNMENT AND INSTITUTION
- COLABORATION
- MULTI YEAR COMMITMENT
- LEVERAGE ALBERTA BUSINESS
- NG FUELING STATIONS AS BACKBONE
- DEMONSTRATE AND DOCUMENT LEADING TECHNOLOGY SOLUTIONS IN VEHICLES
- FOCUS ON H2 OPPORTUNITIES
  - combustion engines to fuel cells

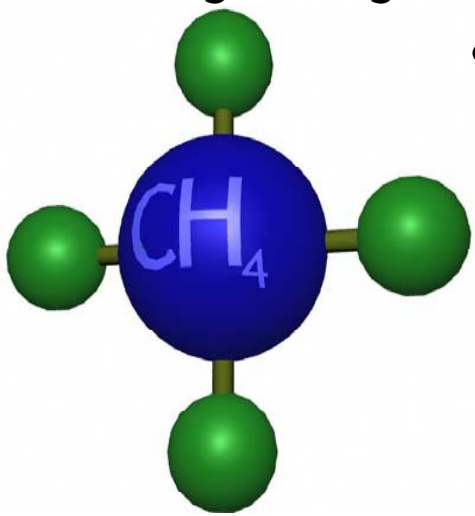
Dynamic Hydrogen Multifuel

- DHM is AFS' Lane on the Bridge
- Flexible, synergistic combination of natural gas and hydrogen with current internal combustion engine economics
- Allows practical operation even if one of the two fuels is unavailable – a critical feature of any bridging technology
- Patent Pending

Fuel Characteristics

- Hydrogen
  - excellent low-torque fuel (wide flammability window, thorough combustion, works best with excess air)
  - poor high-torque fuel (knock prone, octane number ~68, displaces ~30% air, danger of high NO_x.





- Natural Gas
  - excellent high-torque fuel (methane octane number=130)
  - poor low-torque fuel (fussy air:fuel ratio), difficult to catalyze unburnt hydrocarbons.

Green Corridor Plan

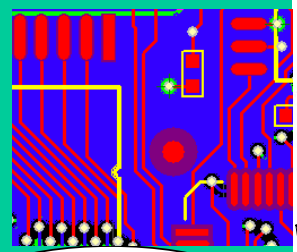
DHM Demonstration Program Participants

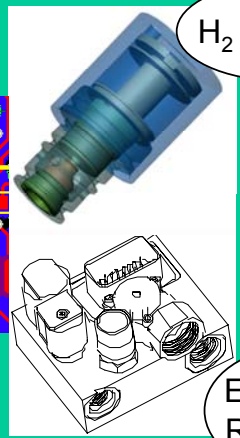
- Fleet Operator
- AFS-DHM Technology
- OEM
- Cylinder Supplier
- Re-Fuelling Station Supplier & Operator
- Utilities
  Compressed Natural Gas & Electricity
- Hydrogen Generator

5,000 psi H_2 cylinder

3,600 psi CNG cylinder

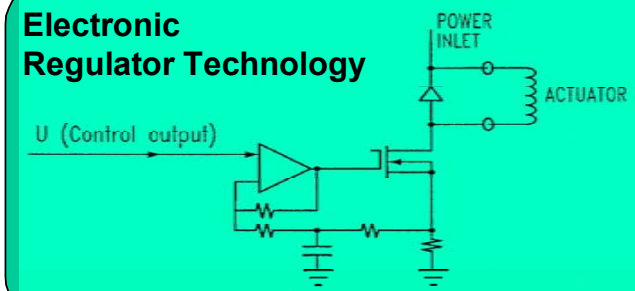
AFS – DHM Technology

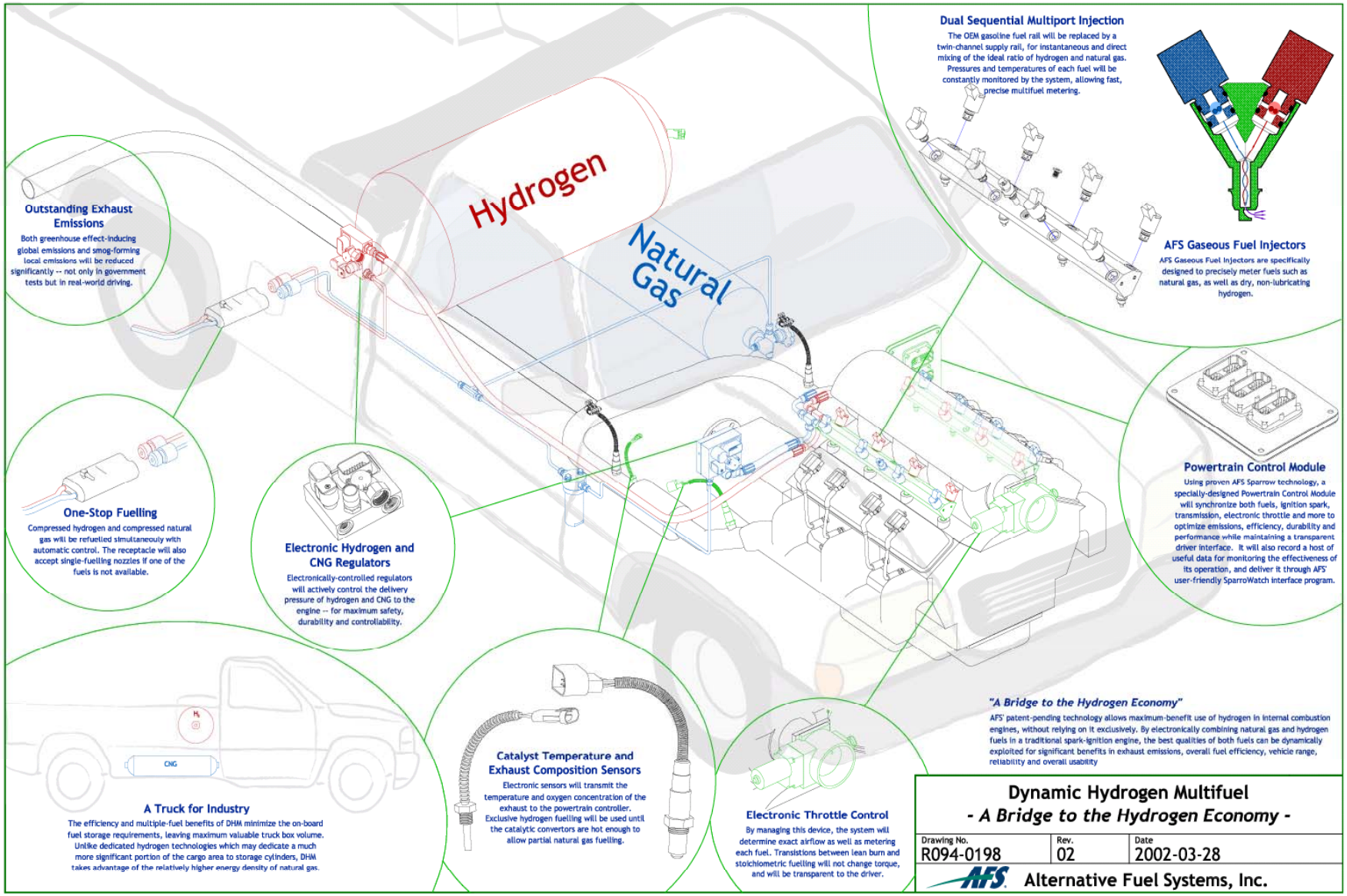




- H_2 Injectors
- Powertrain Control Module
- Electronic Regulator

Electronic Regulator Technology





Outstanding Exhaust Emissions

Both greenhouse effect-inducing global emissions and smog-forming local emissions will be reduced significantly -- not only in government tests but in real-world driving.

One-Stop Fuelling

Compressed hydrogen and compressed natural gas will be refuelled simultaneouly with automatic control. The receptacle will also accept single-fuelling nozzles if one of the fuels is not available.

Electronic Hydrogen and CNG Regulators

Electronically-controlled regulators will actively control the delivery pressure of hydrogen and CNG to the engine -- for maximum safety, durability and controllability.

A Truck for Industry

The efficiency and multiple-fuel benefits of DHM minimize the on-board fuel storage requirements, leaving maximum valuable truck box volume. Unlike dedicated hydrogen technologies which may dedicate a much more significant portion of the cargo area to storage cylinders, DHM takes advantage of the relatively higher energy density of natural gas.

Catalyst Temperature and Exhaust Composition Sensors

Electronic sensors will transmit the temperature and oxygen concentration of the exhaust to the powertrain controller. Exclusive hydrogen fuelling will be used until the catalytic convertors are hot enough to allow partial natural gas fuelling.

Electronic Throttle Control

By managing this device, the system will determine exact airflow as well as metering each fuel. Transistions between lean burn and stoichiometric fuelling will not change torque, and will be transparent to the driver.

Dual Sequential Multiport Injection

The OEM gasoline fuel rail will be replaced by a twin-channel supply rail, for instantaneous and direct mixing of the ideal ratio of hydrogen and natural gas. Pressures and temperatures of each fuel will be constantly monitored by the system, allowing fast, precise multifuel metering.

AFS Gaseous Fuel Injectors

AFS Gaseous Fuel Injectors are specifically designed to precisely meter fuels such as natural gas, as well as dry, non-lubricating hydrogen.

Powertrain Control Module

Using proven AFS Sparrow technology, a specially-designed Powertrain Control Module will synchronize both fuels, ignition spark, transmission, electronic throttle and more to optimize emissions, efficiency, durability and performance while maintaining a transparent driver interface. It will also record a host of useful data for monitoring the effectiveness of its operation, and deliver it through AFS' user-friendly SparroWatch interface program.

"A Bridge to the Hydrogen Economy"

AFS' patent-pending technology allows maximum-benefit use of hydrogen in internal combustion engines, without relying on it exclusively. By electronically combining natural gas and hydrogen fuels in a traditional spark-ignition engine, the best qualities of both fuels can be dynamically exploited for significant benefits in exhaust emissions, overall fuel efficiency, vehicle range, reliability and overall usability

Dynamic Hydrogen Multifuel

- A Bridge to the Hydrogen Economy -

Drawing No.	Rev.	Date
R094-0198	02	2002-03-28

AFS Alternative Fuel Systems, Inc.

Why Alberta

- Transportation and distribution hub
- Quantity of light and medium duty vehicles
- Economic diversification
- Emissions credits
- Early H_2 Application
- Encourages NGV
- Leverage our energy advantage
- Fosters H_2 strategy

Alberta's Green Energy Corridor

MISSION

PROVIDE A WORKING INFRASTRUCTURE FOR THE DEMONSTRATION , VERIFICATION AND ADOPTION OF LEADING TECHNOLOGY SOLUTIONS TO REDUCE HARMFUL EXHAUST EMISSONS FROM INTERNAL COMBUSTION ENGINES.

VISION

ALBERTA BUSINESS PRO-ACTIVLY ENGAUGED IN THE TESTING AND UTILIZATION OF CLEANER FUELS FOR TRANSPORTATION NEEDS

GOAL

TO ESTABLISH ALBERTA AS A LEADER IN FOSTERING A COLABORATIVE ENVIRONMENT TO EMBRASE TRANSPORTATION EMISSIONS REDUCTION