Ford Technology & Iceland as a Proving Ground

North Atlantic Hydrogen Association Conference

Reykjavik, Iceland

Dr. Scott M. Staley, P.E.
Chief Engineer

Outline

- Ford Technology – EV, H2ICE, FCEV
- Ford Focus FCEV – Experience to date
- Iceland as a Proving Ground
- Prospects for a Hydrogen Future

Ford EV Technology

1992 - 1993 Ford Ecostar

1998 - 2000 Ford Ranger
and Postal Program

2001 Th!nk city

2002 Th!nk neighbor

Ford H2ICE Technology

2.0L I4

2001 - P2000

2.3L Supercharged I4

2003 – NAIAS Model U

2003 – H2ICE Focus

2004 – H2ICE C-Max

2003 – Centennial H2RV

2005 – H2ICE Hybrid Bus (Designline)

6.8L Boosted V10

2006 – H2ICE Demo/Fleet

2004 – H2ICE Generator (Generac)

2004 – H2ICE Hybrid Bus (ISE)

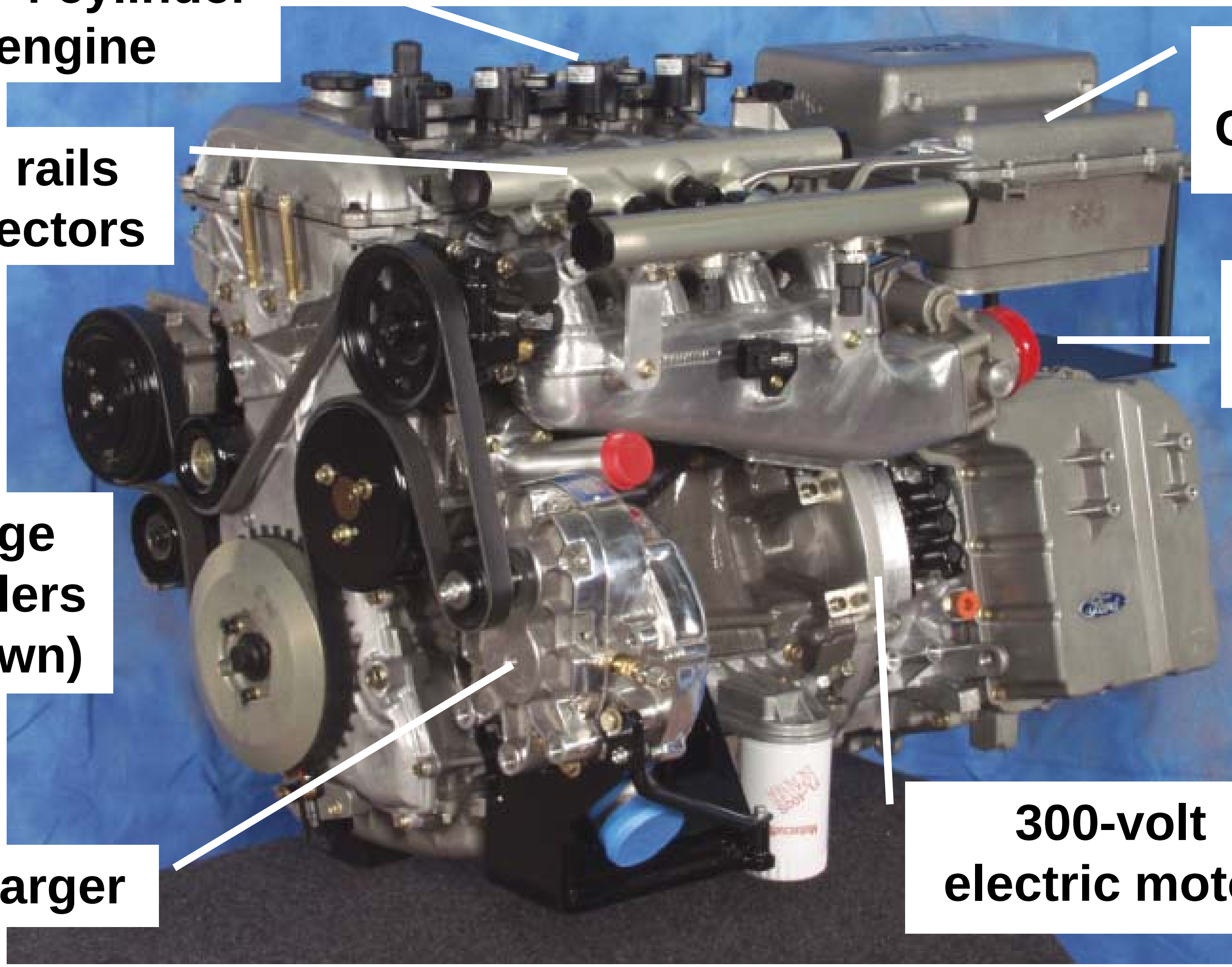
2004 – H2ICE Rotary (Mazda)

2006 – 4.2L V-6

Ford Model U - Hydrogen ICE

Bob Natkin, Group Leader Hydrogen Internal Combustion Engine

H_2 ICE-HEV Powertrain Generation II




Ford
H_2 Powered V10
Ford
H2ICE

Unique H2ICE Hardware

Fuel Rail Assemblies
-Greater Volume

Intake Manifold
-Purpose Designed

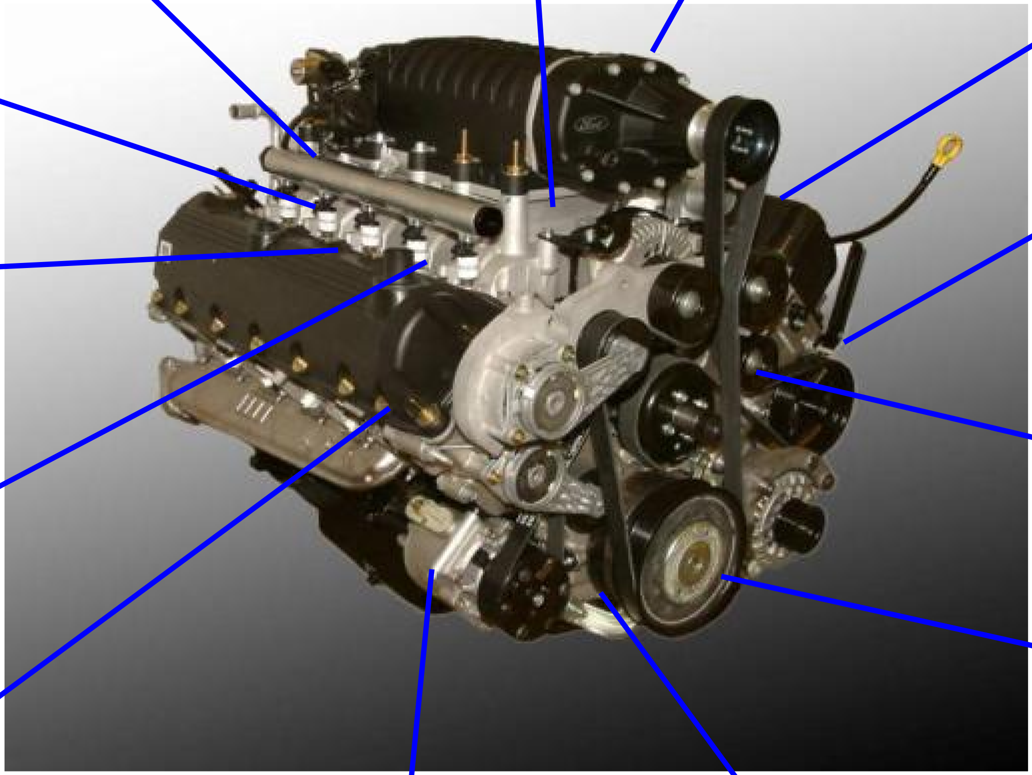
Supercharger/Intercooler
-3300cc Twin Screw
-Water-to-air intercooler

Fuel Injectors
-Designed for H2

PCV System
-External oil separator

Spark Plug
-Iridium tipped

FEAD
-Supercharger
-2nd alternator



Head Gasket
-Rated for 100 bar

Ignition Coil
-High energy

Damper
-Tuned for H2 combustion

Valves/Seats
-Premium material

Piston/Rod/Rings
-Forged Eutectic piston
-Forged steel rods

New oil formulation
-Low ash content
-Extra corrosion inhibitors

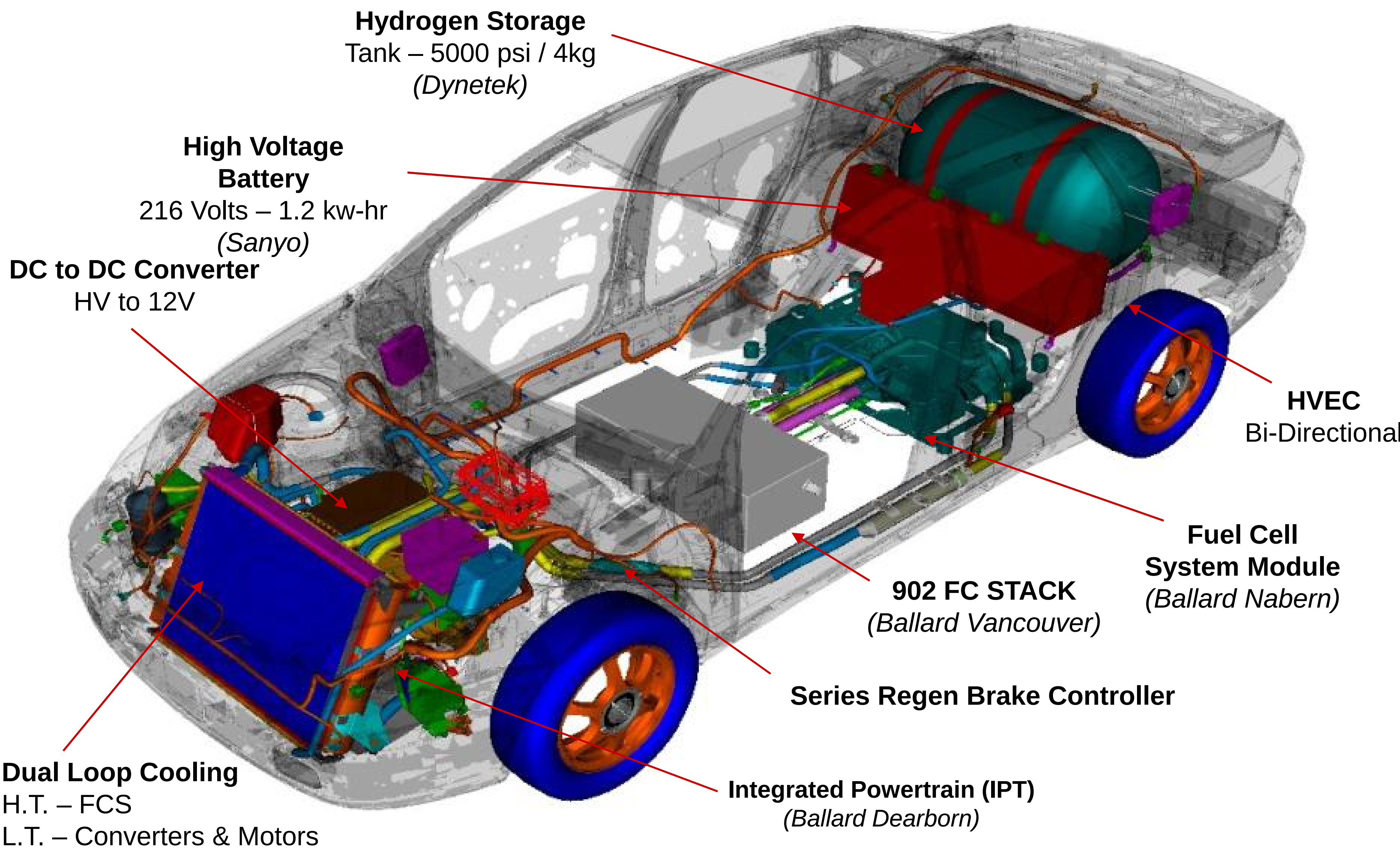
Ford FCEV – Experience to date

Ford Fuel Cell Vehicle Technology
P-2000 FCEV

2005 Focus Fuel Cell Vehicle

- Ford Focus 4 Door
- Curb Mass: 1600 kg (3520 lbs)
- Fuel Cell: Ballard Mark 902 FC STACK
- Power: 68kW (87hp)
- Powertrain: Integrated AC Induction
- Hybridized – 216 volt Battery Pack
- Series Regenerative Braking
- City = 48 Mi/Kg H_2 (49 MPG gas equivalent)
- Hwy = 53 Mi/Kg H_2 (54 MPG gas equivalent)
- Range: 200 mi/320 km
- Max speed: 80+ mph/128+ kph
- Fuel: 5000 psi Compressed Hydrogen
- Emissions: Zero
- Cold Start Capability > 2 C
- Operational Capability: –15 C up to 50 C

FCV Architecture - Key Subsystems



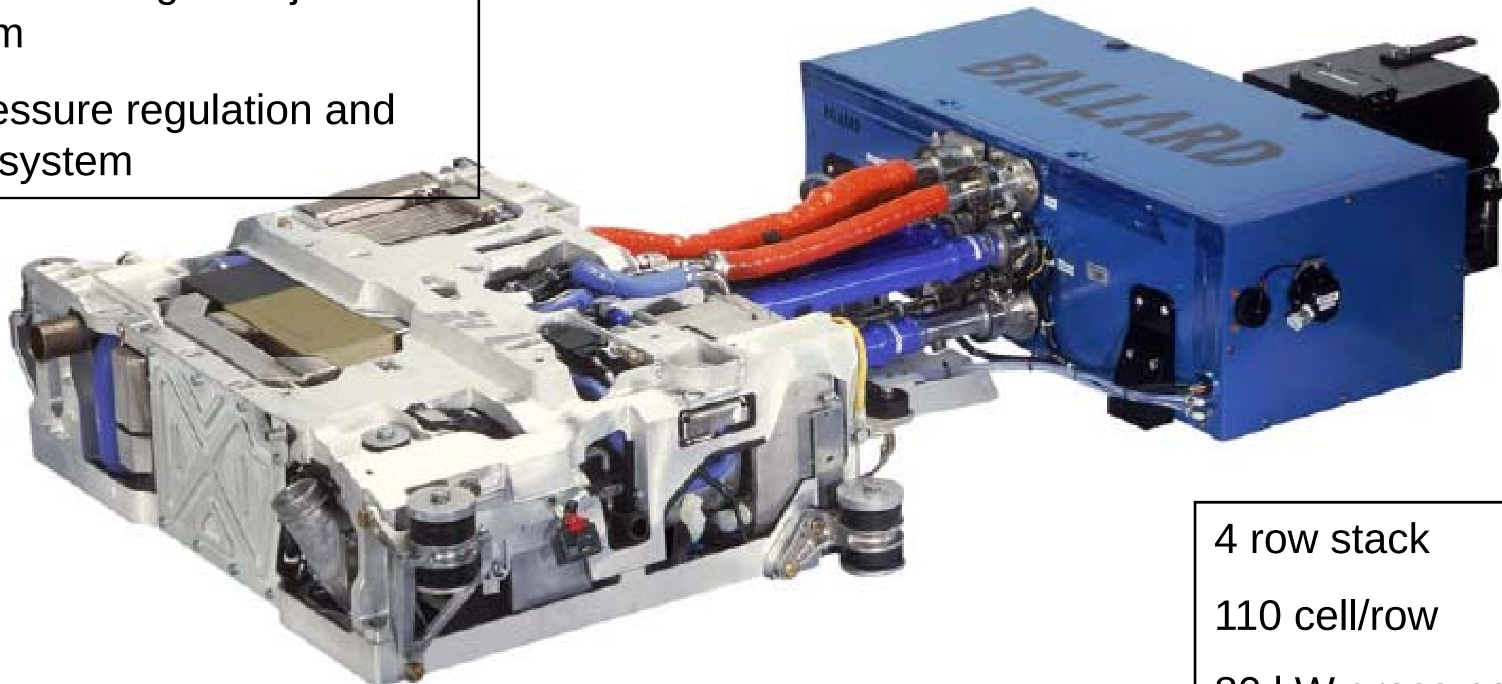
Ballard Fuel Cell Engine

Air Compressor/expander & e-motor drive system

Air/H2 Humidifiers

DI Water storage & Injection System

H2 pressure regulation and recirc system



4 row stack

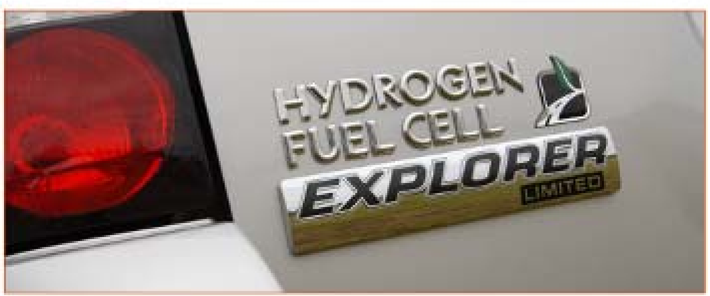
110 cell/row

80 kW gross power

Cell Voltage Monitor

TDV2 in LA Auto Show

2006 L.A. Auto Show: Ford Explorer Fuel Cell



Ford is debuting what looks like a standard Explorer SUV in L.A. this week, but it actually packs a hydrogen powertrain; a tank of the alternative fuel can take the Explorer 350 miles on a single fill-up.

The fuel cell prototype is partially funded by the U.S. Department of Energy in order to show a viable alternative to petroleum. We'd have to assume the government wouldn't want to invest in any hydrogen infrastructure without seeing some real working samples on the road.

The fuel cell Explorer has been tested over more than 17,000 miles, and traveled 1,556 miles in a 24-hour period. Ford will also launch its next-generation Escape and Escape Hybrid compact SUVs tonight at midnight.

TDV7 – Ford Edge with HySERIES Drive

207 mph (330 kph)

Iceland as a Proving Ground

Ford Corporate Testing Procedures

Vehicles Robustness and Durability Testing

14,000 Ft Altitude Testing

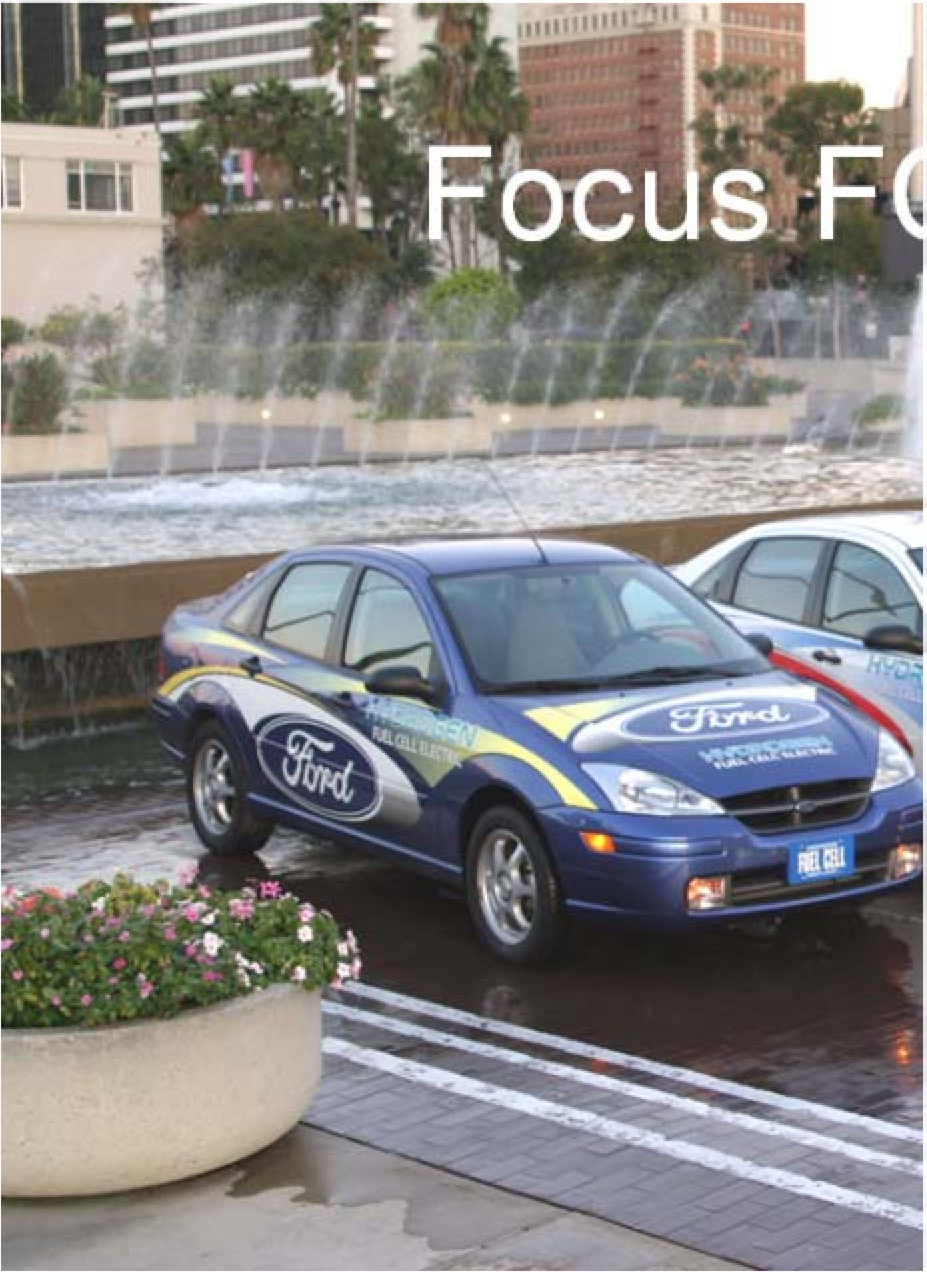
Mud Bath / Salt Water Fording

90° Fixed Barrier Impact

Sault Ste Marie Brake Testing -18 C

Cobblestone Roads

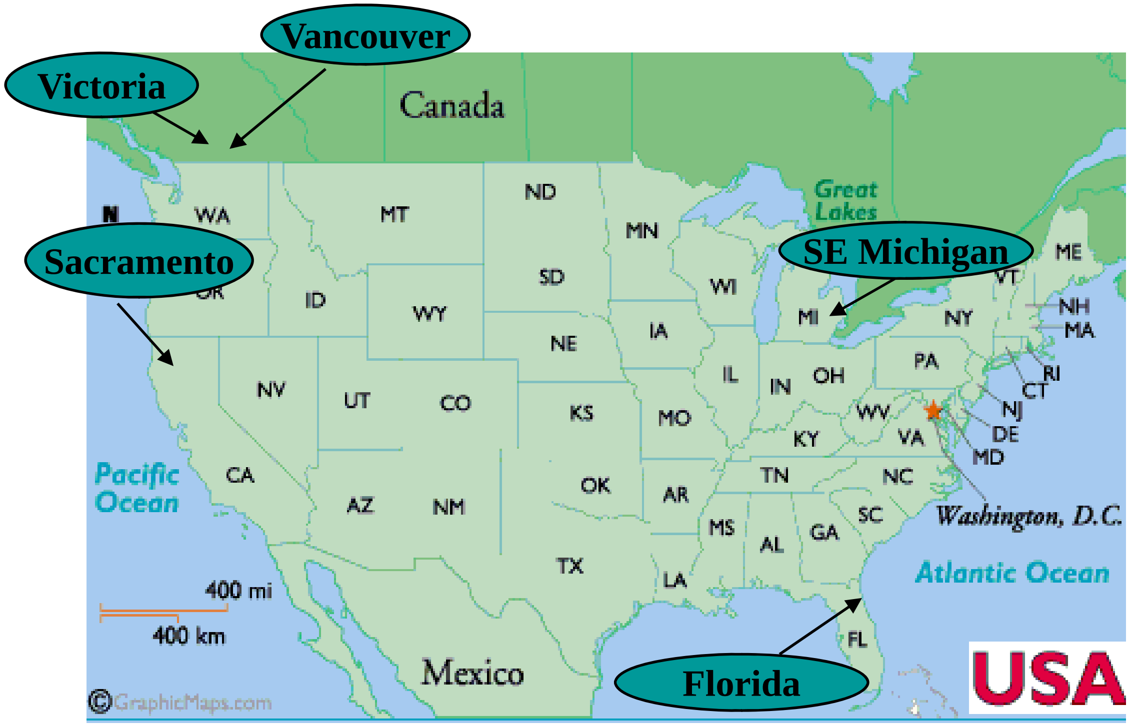
90° Moving Barrier Impact



Focus FCV Demonstration

- 3 years
- 30 vehicles (18 in DOE)
- 750,000 miles
- 150 participants
- 9 fueling locations
- 95% up time

Ford Focus FCEV Vehicle Locations



- 32 FCV in operation worldwide (US, Canada & Germany)
- 27 Vehicles Delivered to 7 Customer locations
- 18 Vehicles in the DOE-funded Demonstration Fleet
- 5 Engineering vehicles used between Dearborn and Sacramento

Canada

Fuel Cells Canada™

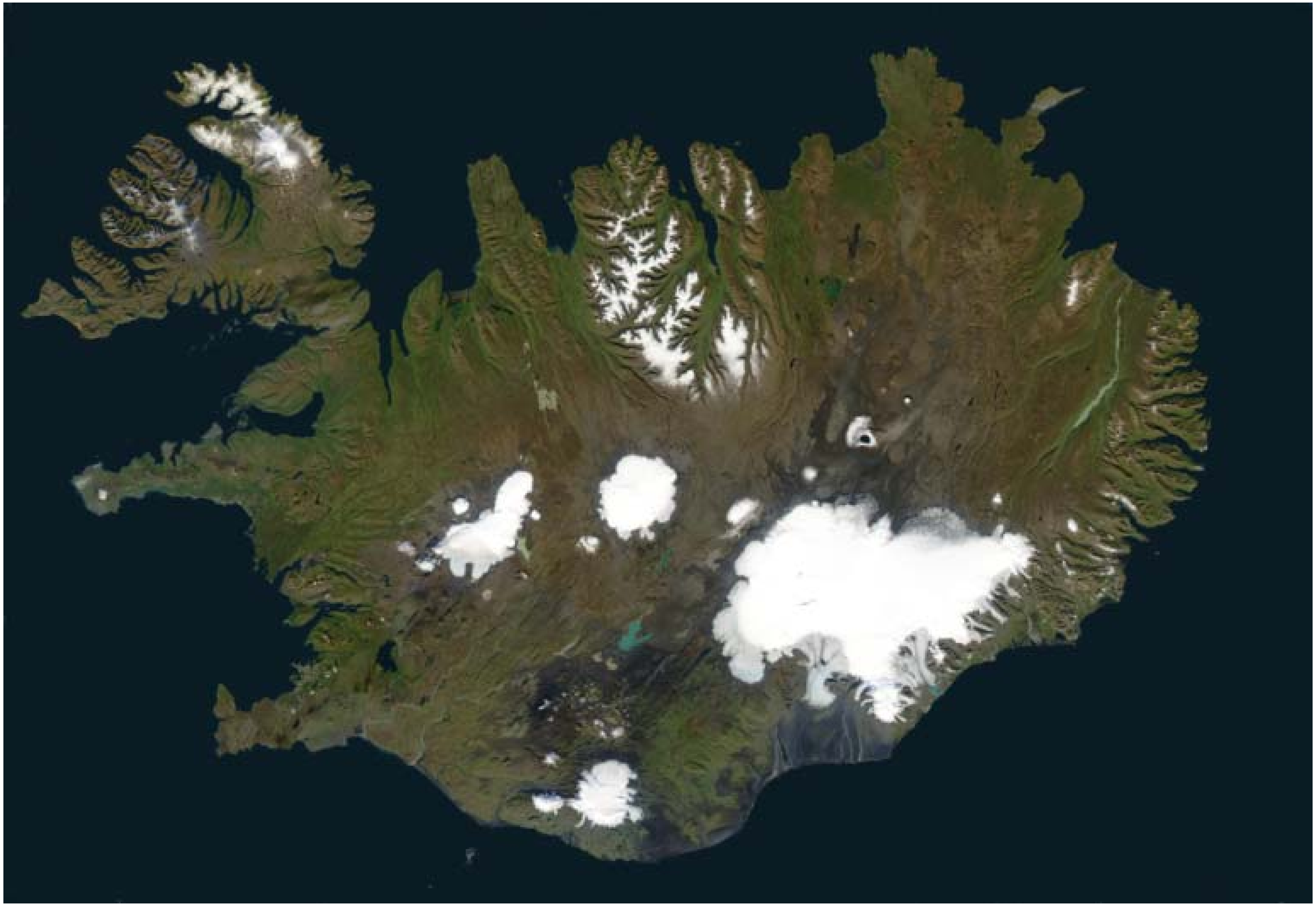
BRITISH COLUMBIA

Ford

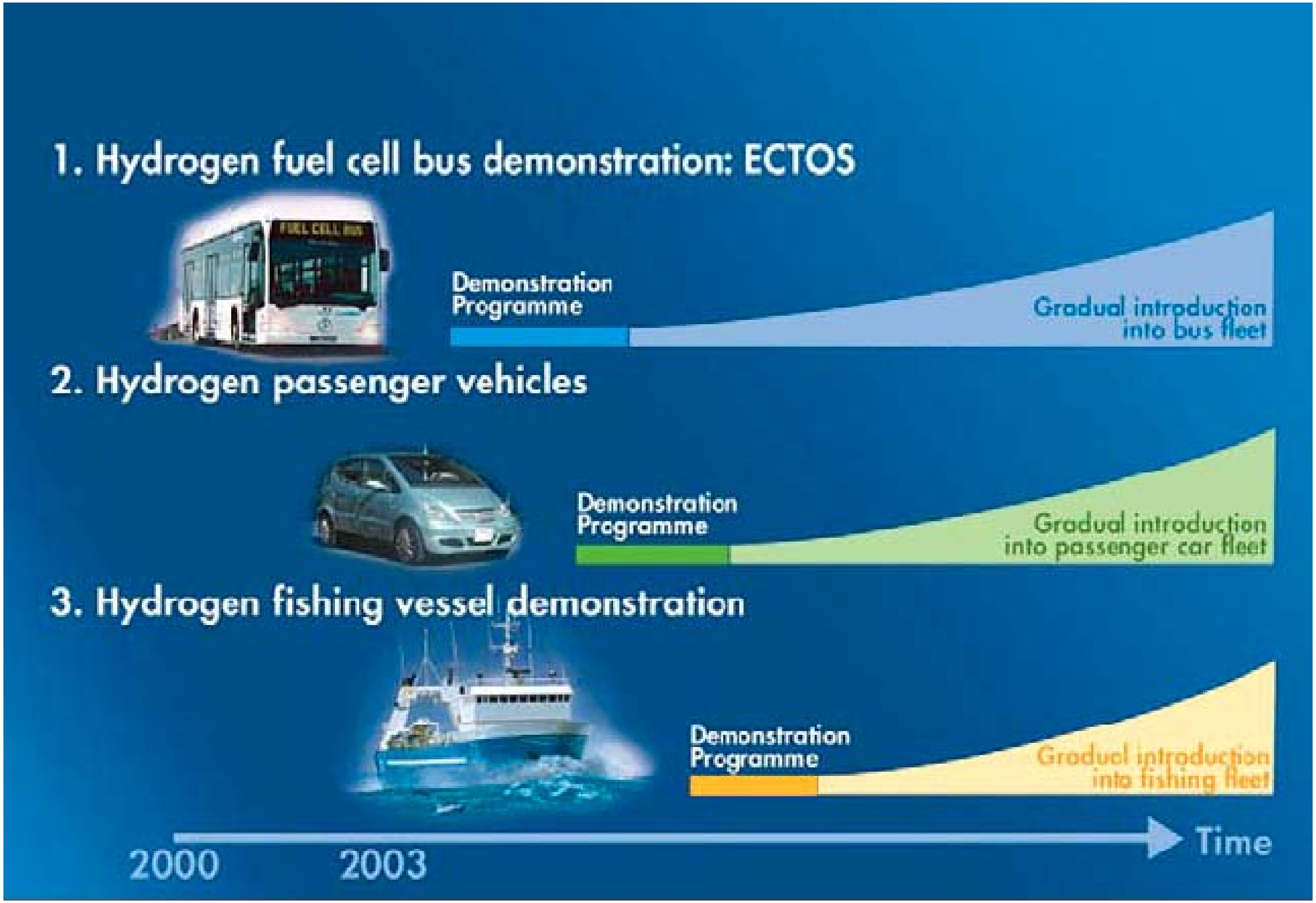
NHA Annual Hydrogen Conference 2006
Long Beach, California

Berlin CEP

And Now, Iceland



Iceland has a Plan



Iceland has Hydrogen Infrastructure

Iceland has Experience

Iceland has Technical and Scientific Contributions

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Implementing the hydrogen economy

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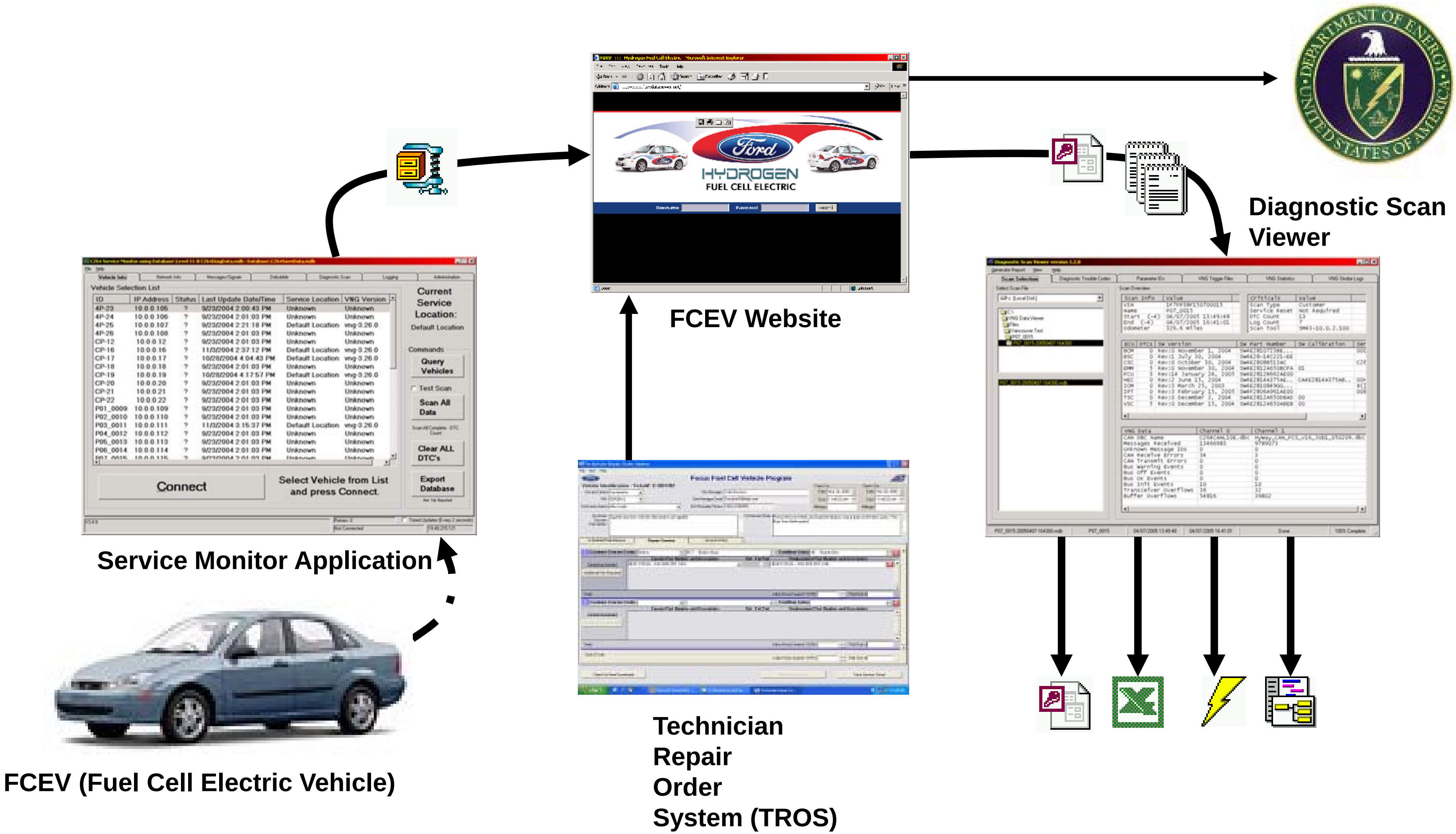
Abstract

In the Icelandic community the use of renewable energy and the tests with a clean domestic fuel that most people refer to as the fuel of the future have become the points of focus. In Reykjavik this future has arrived. Hydrogen is used currently as the energy carrier within the public transportation system and is electrolyzed from water with hydroelectric power and leaves the system as water again.

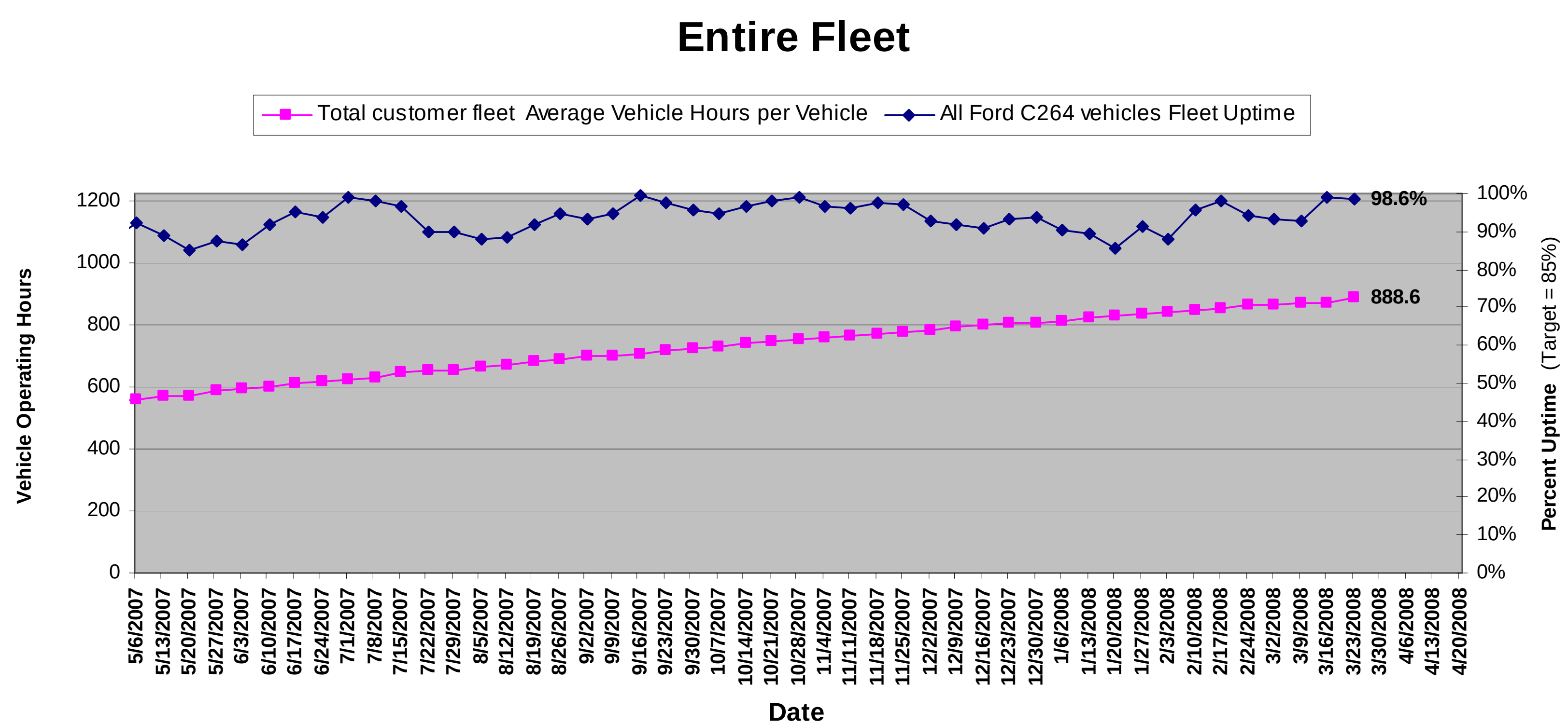
Figure 1. The fuel cell bus at the filling station

The US DOE, Ford and INE add another FCV to the Iceland Fleet

Fleet Data Collection & Reporting



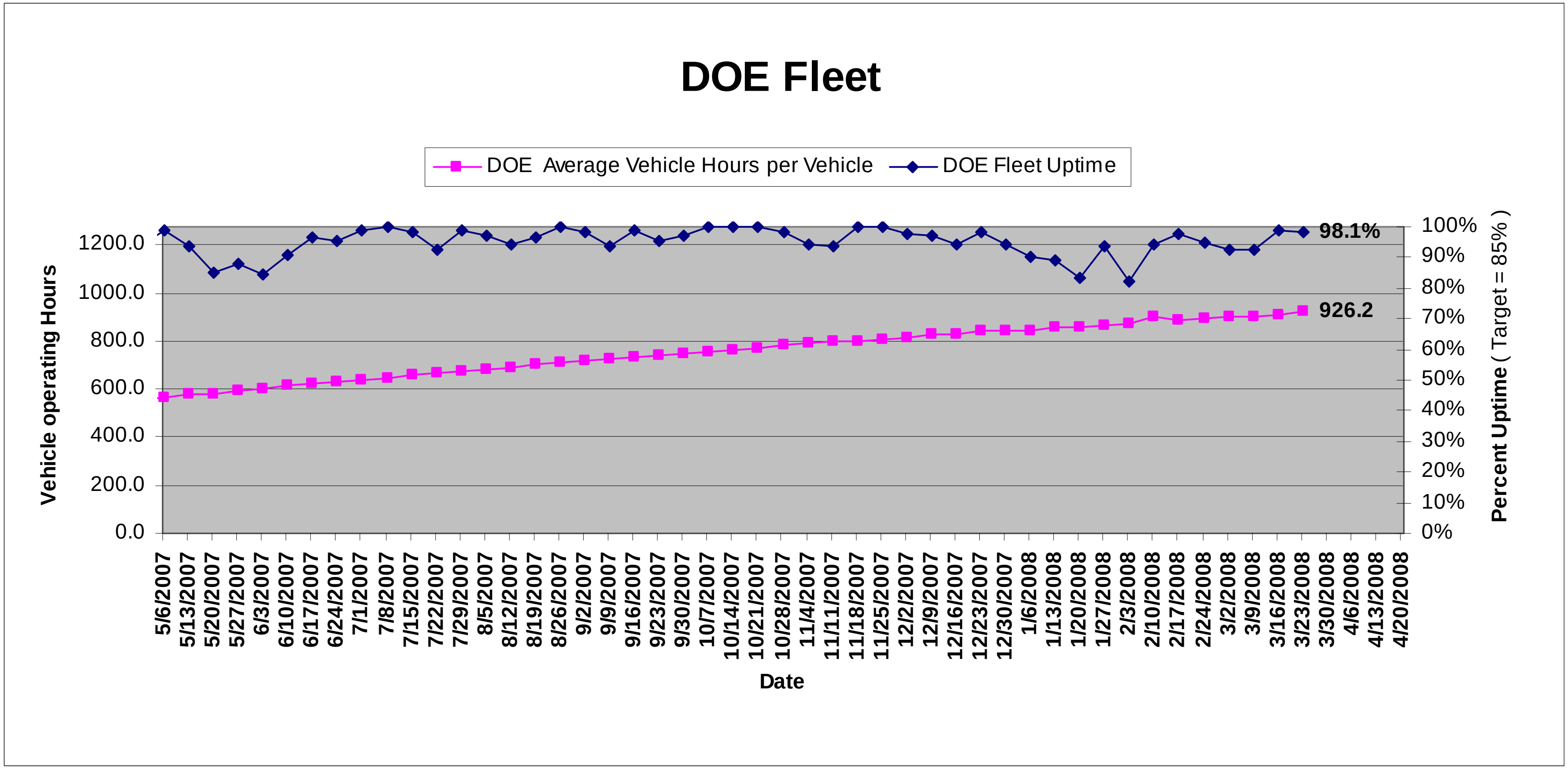
Entire Fleet



Total Customer Fleet Miles Accumulated	Total Customer Fleet Hours Accumulated
637270	21149

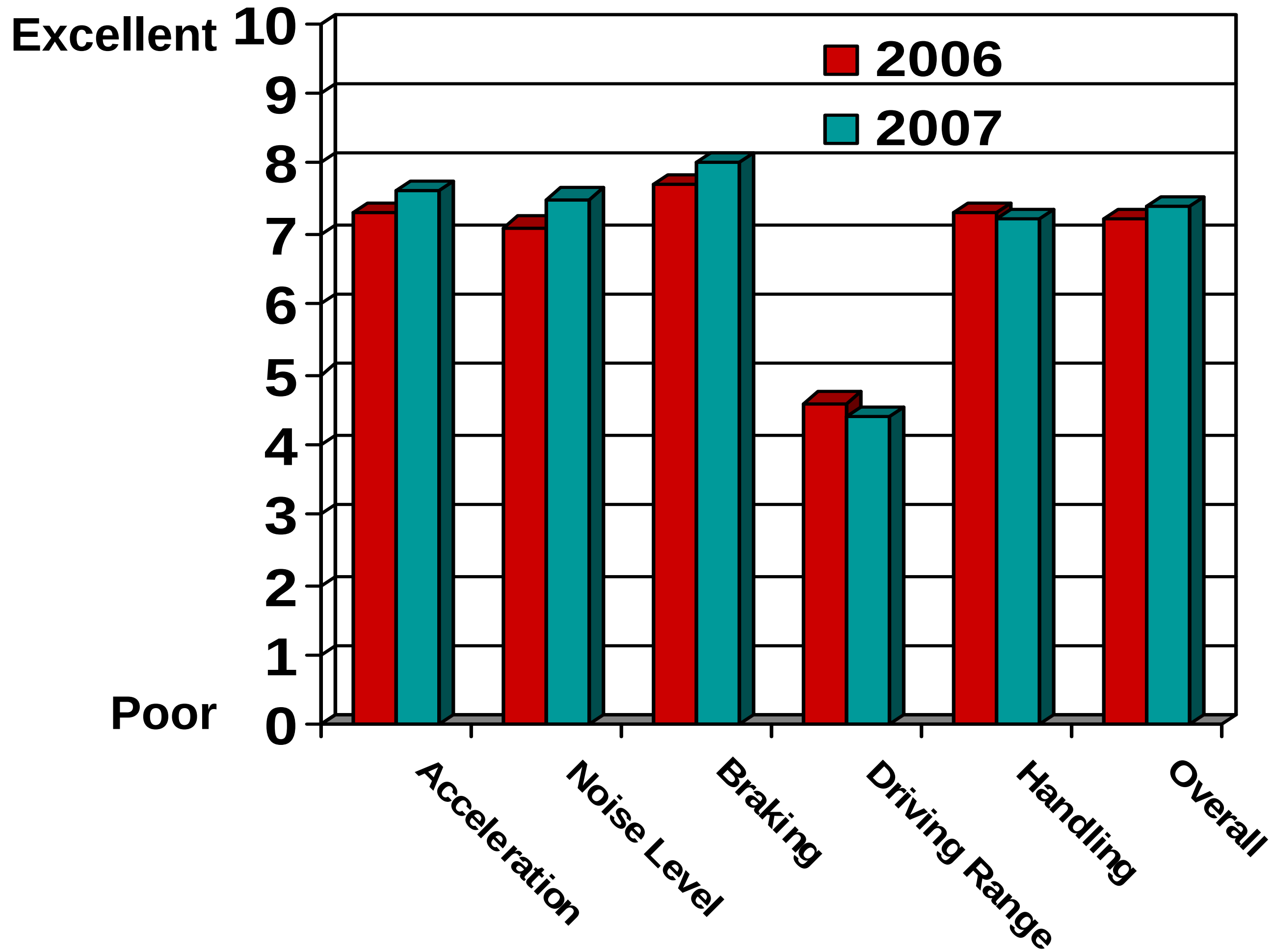
Total Running Fleet Miles Accumulated	Total Running Fleet Hours Accumulated
748477	23068

DOE Vehicles

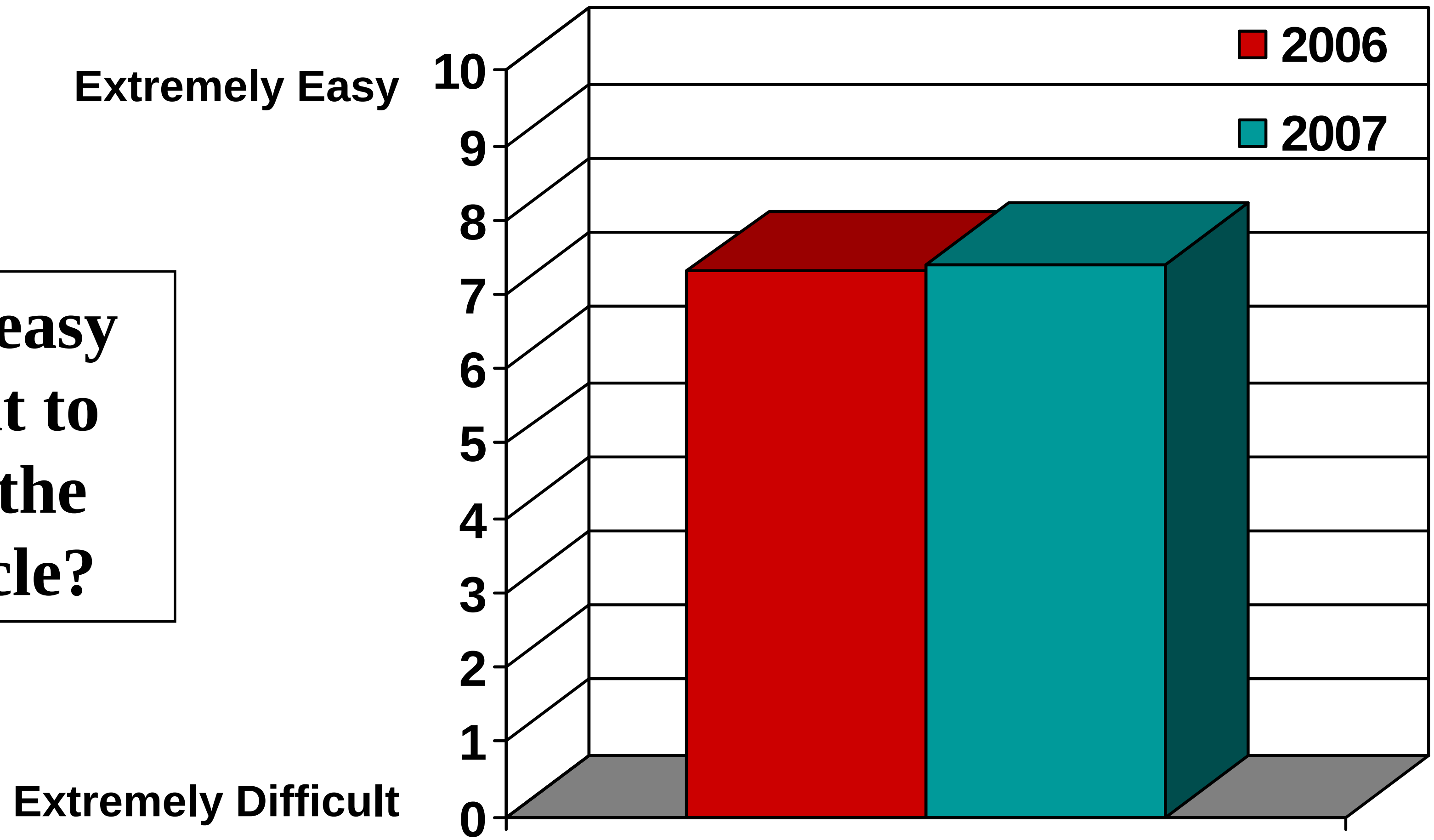


Highlights from Fleet Customer Survey

How would you rate the vehicle's performance?



Highlights from Fleet Customer Survey



How easy was it to fuel the vehicle?

52 respondents in 2007

The Hydrogen Future Bookends

Conclusions with Respect to a Sustainable Energy Future

A sustainable energy future must be based on energy from renewable sources and energy efficiency

Hydrogen must be fabricated from renewable electricity

By laws of physics much energy is needed (and lost) for producing, packaging, distributing, storing and using hydrogen: (Losses about 50% for gaseous hydrogen and 75% for electricity from fuel cells)

Hydrogen cannot compete with its own energy source:
RENEWABLE ELECTRICITY

Therefore, a global "Hydrogen Economy" has no future!

In fact, the hasty implementation of a Hydrogen Economy may block the establishment of a sustainable energy future based on electricity from renewable sources

35

Ulf Bossel, Ph.D., October 2004

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Wind energy and the hydrogen economy—review of the technology

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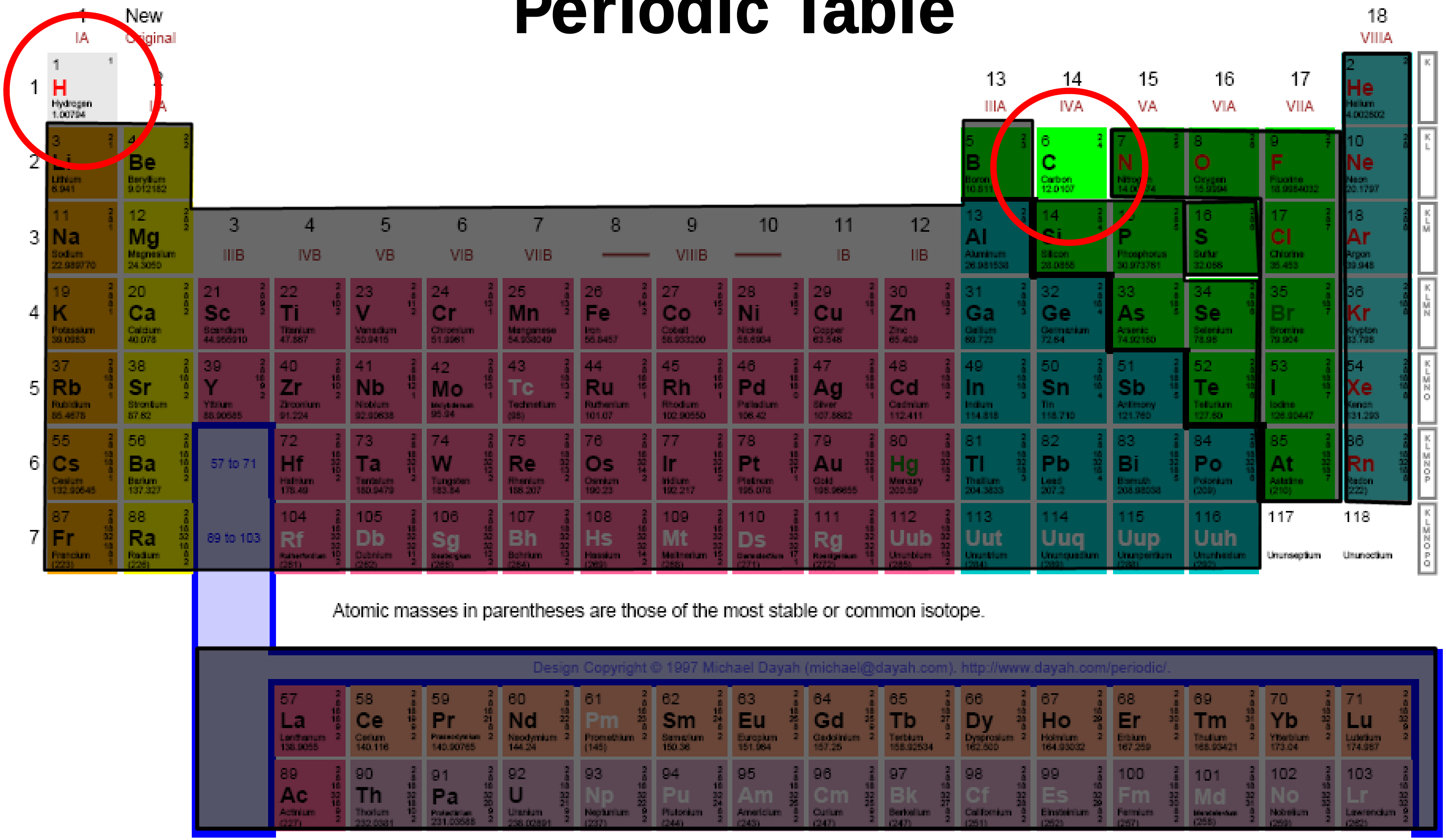
Abstract

The hydrogen economy is an inevitable energy system of the future where the available energy sources (preferably the renewable ones) will be used to generate hydrogen and electricity as energy carriers, which are capable of satisfying all the energy needs of human civilization. The transition to a hydrogen economy may have already begun. This paper presents a review of hydrogen energy technologies, namely technologies for hydrogen production, storage, distribution, and utilization. Possibilities for utilization of wind energy to generate hydrogen are discussed in parallel with possibilities to use hydrogen to enhance wind power competitiveness.

Keywords: Hydrogen energy; Wind energy; Fuel cells; Solar energy; Hydrogen production; Hydrogen storage

Periodic Table



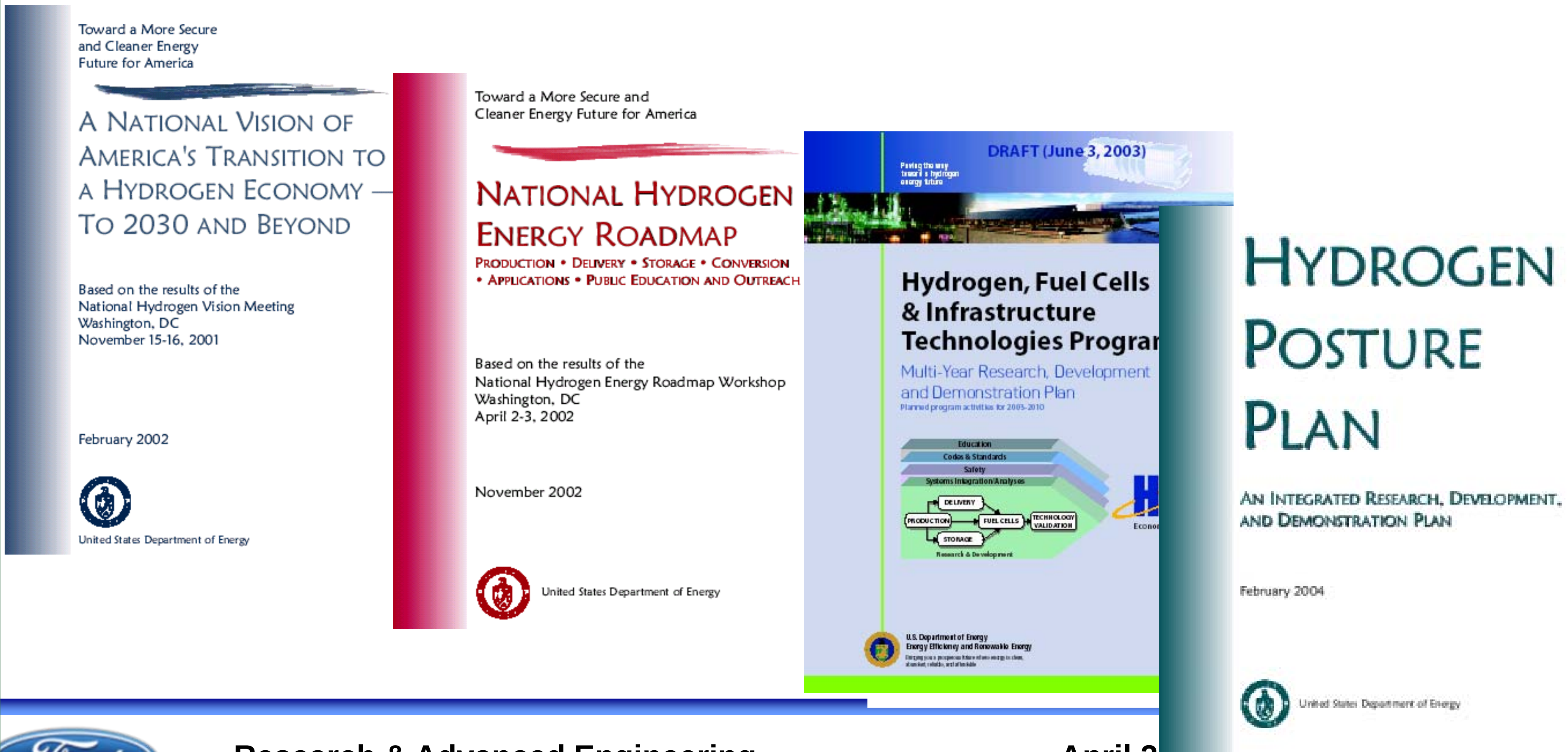
Conclusion: hydrogen and carbon are the only important elements in transportation fuels.

Wheel-to-Wells Findings

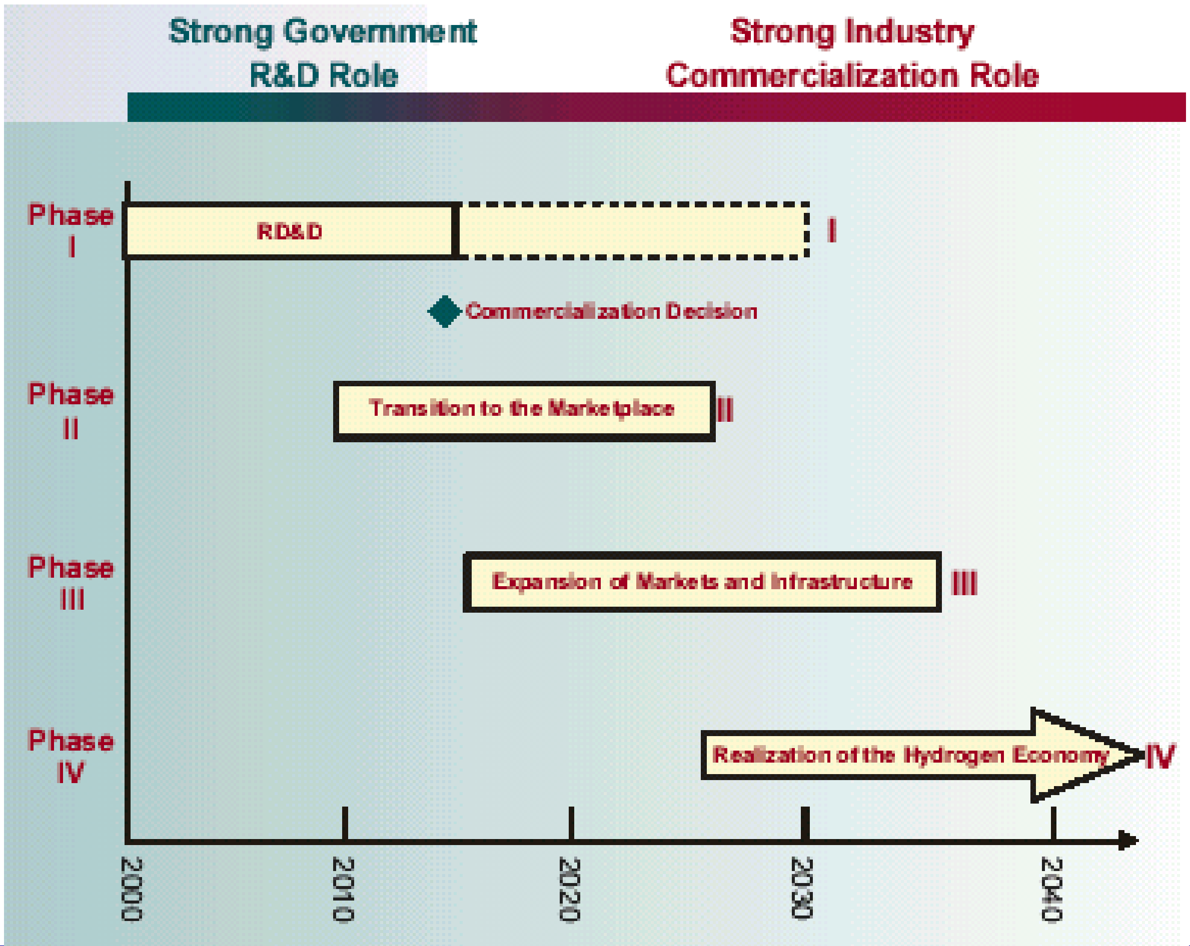
- **Electricity would be the ideal transportation fuel.**
  - **Lowest CO_2 impact with today's generation mix.**
  - **Distribution infrastructure is already in place.**
  - **But … on-board storage – meaning range - and recharge time are unacceptable**
- **Hydrogen (for fuel cells) from natural gas is the best chemical fuel.**
  - **But … Depends on limited fossil fuel resource**
  - **On-board storage remains a major challenge**
  - **No existing retail infrastructure**
  - **Fuel cell systems are much more expensive than ICE**
- **Hydrocarbon from fossil petroleum is the poorest fuel on a CO_2 basis.**
  - **But … is the most practical in the vehicle**
  - **Retail distribution and infrastructure are in place**
  - **Efficiency improvements continue to be made (HEV, PI-HEV, S-HEV)**

U.S. DoE Hydrogen Activities

Hydrogen, Fuel Cells and Infrastructure Technologies Program



DOE Hydrogen Plan



Transitional Phases

I. Technology Development Phase

Research to meet customer requirements and establish business case leads to a commercialization decision

II. Initial Market Penetration Phase

Portable power and stationary/ transport systems begin commercialization; infrastructure investment begins with governmental policies

III. Infrastructure Investment Phase

H_2 power and transport systems commercially available; infrastructure business case realized

IV. Fully Developed Market and Infrastructure Phase

H_2 power and transport systems commercially available in all regions; national infrastructure

Can it be done?

Should it be done?

With the following clear trends:

- **$117/barrel Oil**
- **Emerging world economies (China, India, etc.)**
- **Global environmental concerns**
- **Energy security concerns**

Something must be done!

Will it be done?

- Can Durability, Freeze-start, and other technical performance attributes be achieved?
- Can On-Board Hydrogen Storage be achieved?
- Can Hydrogen Fuel Supply & Infrastructure be installed?
- Can Codes and Standards be agreed?
- Can Affordability be achieved?
  - simplified system design
  - reduced material cost
  - mass production

The World is NOT Running Out of Energy

But it *is* running out of…

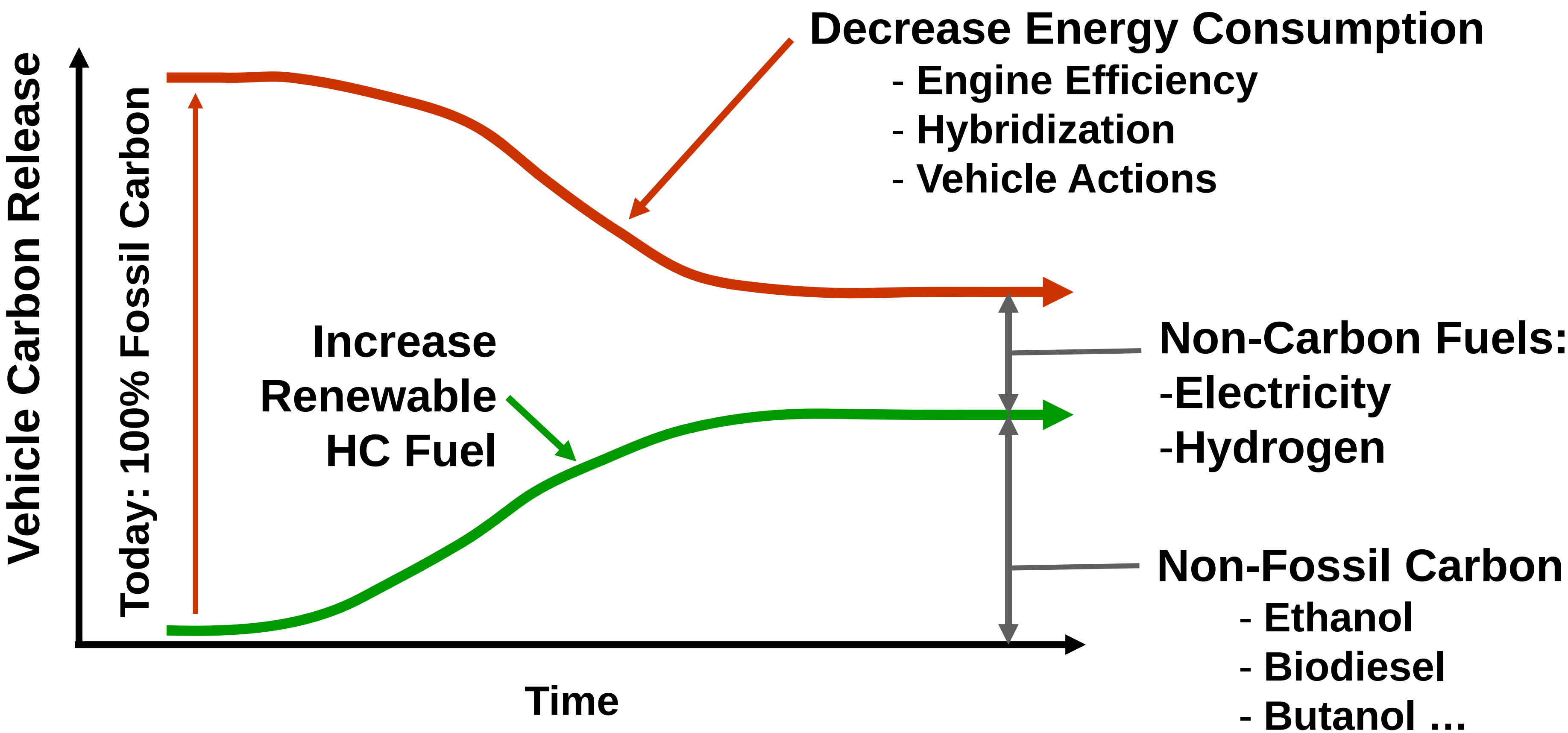
- Cheap oil
- Environmental capacity
- Tolerance for inequity
- Money for better options
- Time for a smooth transition
- Leadership to do what is required

Ford's Portfolio Approach

Use less (fuel)

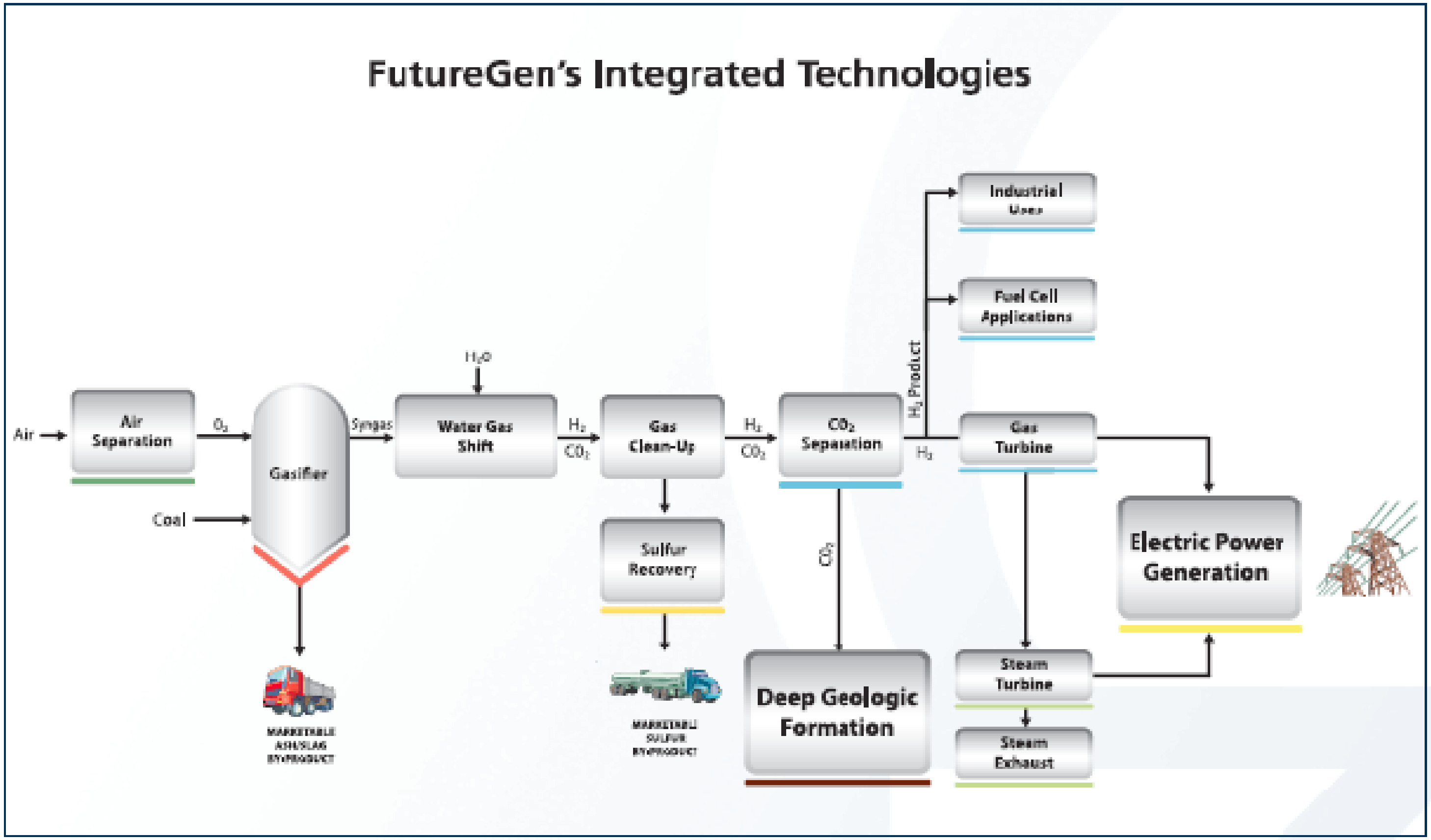
Use renewable (fuel)

Path to CO_2-neutral Transportation



What realistic combinations of fuels and vehicle technologies can drive net CO_2 emission from light-duty transportation to zero?

Integrated Gasification Combined Cycle



Fuel Cell Vehicles

Ford Fuel Cell Technology
In Iceland
April, 2008