

# Fuel Cells and Energy Policy

Andrew R. Thomas

Energy Law & Policy Center – Levin College of Urban Affairs

Cleveland State University

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- Rendition of 2 MW Phosphoric Acid Fuel Cell Power Island

## November

- 11/4 Oil and Gas Policy/Ken Alfred
- 11/6 Shale Revolution
- **11/11 Fuel Cells/Pat Valente**
- 11/13 Transportation Policy/Jim Halloran/(Shale)
- 11/18 Alternative Fuels/Joe Degenfelder/(Shale)
- 11/20 Nuclear Power/Electricity Storage
- 11/25 Economic Development/I. Lendel/Urban Policy
- 11/27 **Individual Meetings on Research –**  
» **Please Schedule in advance**

# *The Promise of Fuel Cells*

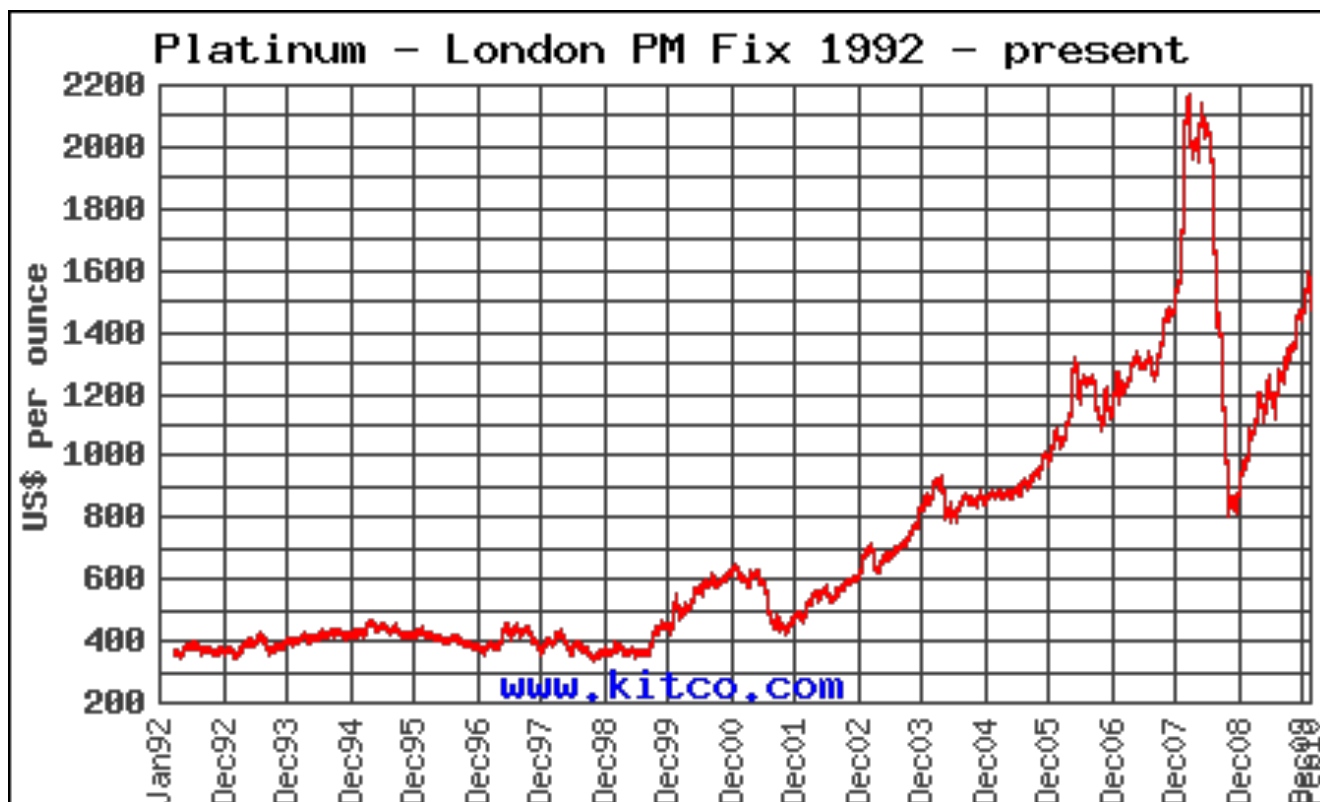
- Clean, dependable power
  - Can marginalize the cost of the grid in places where natural gas is available
  - Very high quality power
  - Zero emissions – byproduct is water
    - Reforming natural gas is not zero emissions
- All sizes – from large scale stationary to portable micropower
- *End of dependency on foreign oil*
- Military/Portability Applications – batteries:
  - Are too bulky to carry in the field
  - Take too long to recharge
  - Are expensive -- \$10,000/kw
- Jobs!

# *The Over Promise of Fuel Cells*

- The “two years away” mentality.
  - Companies have been on the brink of a major breakthrough for twenty years
  - Costs, lifespan, safety issues continue
  - Has overpromise fatigue caused the state and federal government to back away from funding?
    - Or are problems with funding political?
- No resolution to storage or infrastructure problem.
- Still relies on non-renewable source of hydrogen.
- Do fuel cells require a “Nobel Prize” type of breakthrough?
  - Can we replace platinum as the catalyst?

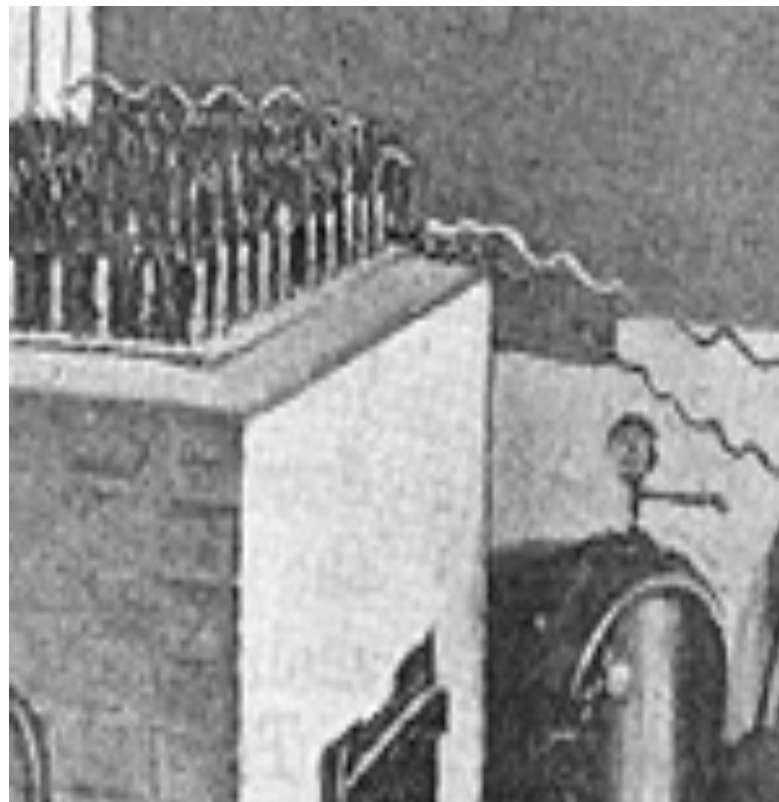
# Platinum Costs Threat

- Catalyst for PAFC and PEM Cell Plants is Platinum.



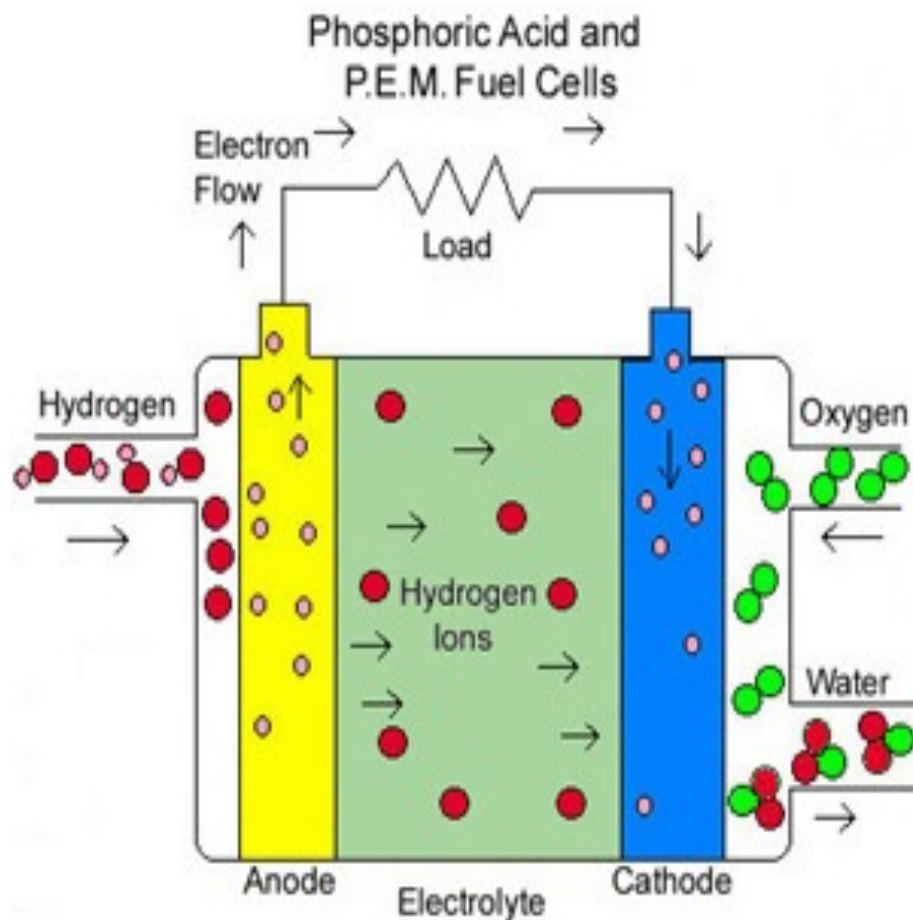
# Fuel Cell History

- Mid 1800s – several inventors used Platinum Catalyst with electrolyte to produce electricity.
- NASA development of fuel cells in the 1960s led to accelerated growth.



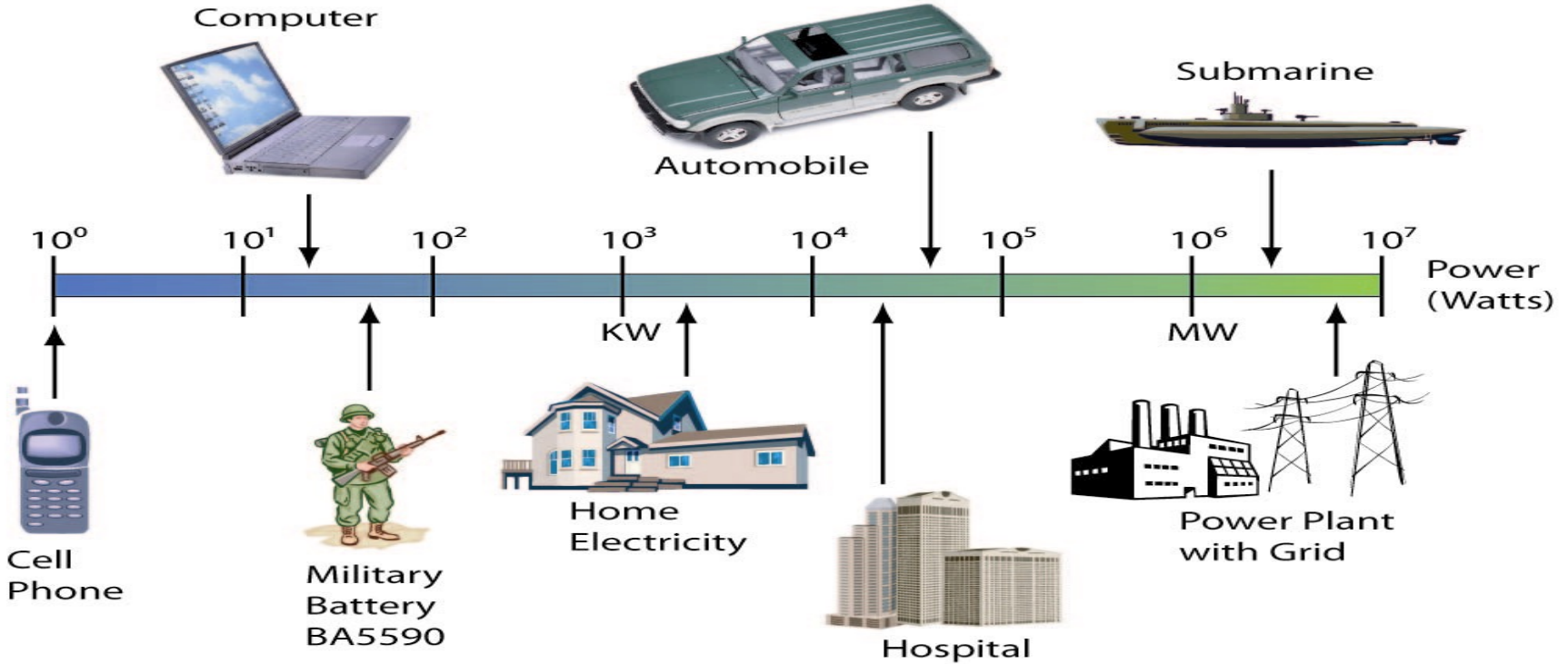
# Basic Fuel Cell Operations

- Hydrogen supplied to anode.
- Oxygen (air) at the cathode.
- Phosphoric acid electrolyte, platinum catalyst.
- Electricity, heat and water produced.



# Generation Range for Fuel Cells

## Fuel Cell Power Spectrum





# The Hydrogen Problem

- Energy carrier, not a primary source of energy
- Commonplace, but does not exist in a free state
  - Requires energy to produce
- Difficult to store and transport – similar to natural gas and electricity
- Near term source: natural gas
  - Carbon dioxide emissions during reformation

# Sources of Hydrogen

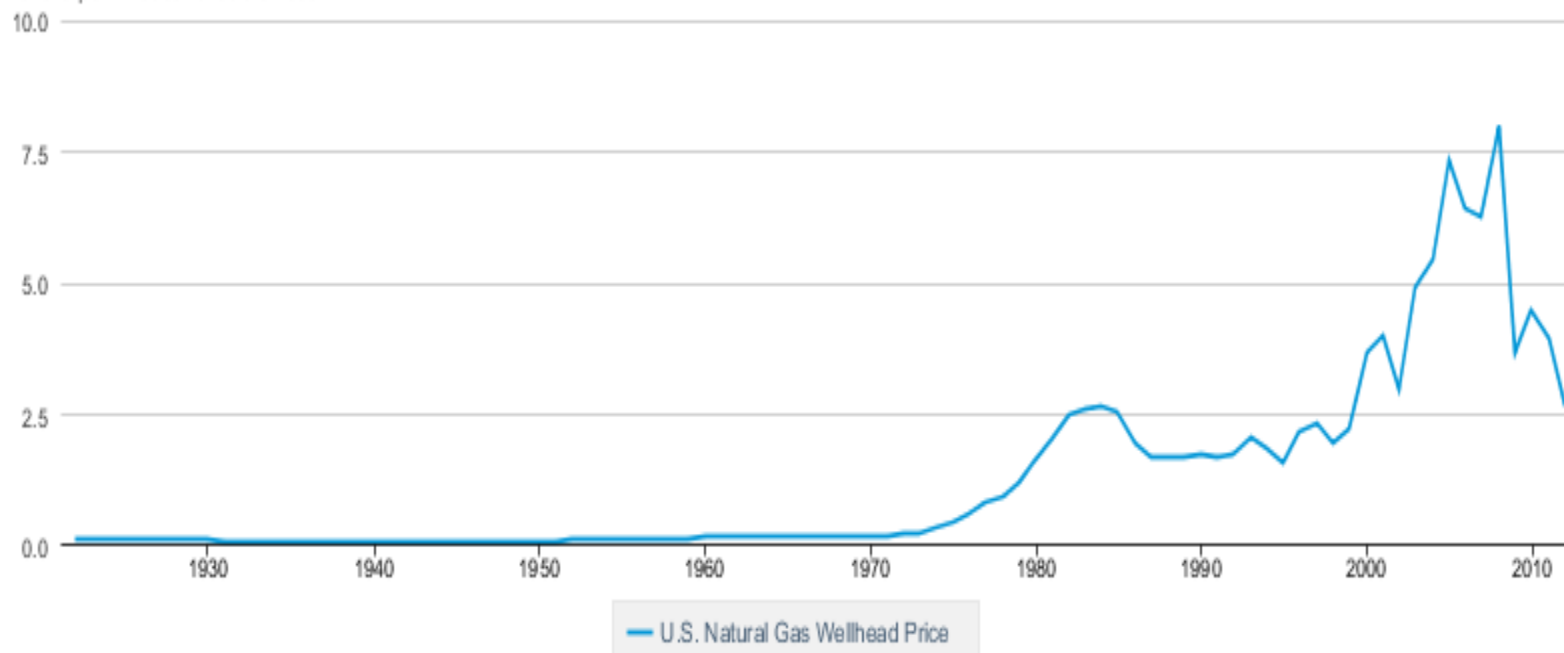
- Steam Reforming of Natural Gas
- Biomass Product (methanol)
- Chemical Processes
- Electrolysis
  - Wind, Solar Energy
  - Nuclear Power



# Driving Down Costs of Hydrogen Reformation

## U.S. Natural Gas Wellhead Price

Dollars per Thousand Cubic Feet



Source: U.S. Energy Information Administration

# Fuel Cell Technologies

- High Temperature Fuel Cells
  - Phosphoric Acid, Molten Carbonate, Solid Oxide
    - Long start up times
    - Can withstand impure hydrogen streams
    - Good for DG, cogeneration
    - Not good for transportation, portability
    - MC, SO technologies very high temperatures
      - Problems with longevity, cost
- Low Temperature Fuel Cells
  - Proton Exchange/Polymer Electrolyte Membrane
    - Good for transportation, portable power
    - No cogeneration capability
    - Good for peak loading
    - Needs very clean hydrogen
    - Problems with durability, cost

# Polymer Electrolyte Membrane (PEM)

- Operates at Low Temperature (175°F).
- Solid electrolyte matrix – less corrosion, very quick start-up/shutdown.
- Low temperature limits co-generation opportunities.



# The Future of Distributed Generation

“All the natural gas industry needs is a gizmo in the basement of your house that converts natural gas into electricity. You don't need the grid at all.”

“The natural gas distribution system is actually more reliable than the aging electric grid.”

David Crane, CEO NRG Energy, *SNL Financial Report, March 22, 2013.*

# Fuel Cells in Distributed Generation

- Early DG applications: at sources of by-product or excess hydrogen.
  - However where cheap hydrogen exists may not be where the best market is for electricity
  - Usually competes with industrial pricing
- Options for onsite fuel cells:
  - Consume electricity on site
  - Deliver electricity to the grid
    - Get displaced generation price
  - Sell electricity to a third party
    - Not allowed under Ohio regulatory law

# What policies will enable fuel cell DG?

- Net metering for all fuel cell applications
  - Retail price for excess power produced
- Removal of standby charges
  - Value for quality and reliability of power
- Standardized interconnection rules
- Upgrade reach of natural gas infrastructure
- Continued exploitation of shale gas
- Value externalities



# Accounting for Externalities in California – Stationary Fuel Cells

Job Creation	0.22-0.26
Health Benefits	2.34-2.54
Avoided CO2 Emissions	0.11-2.21
Avoided Other Emissions	0.11-1.90
Increased Reliability	0.01-0.22
Grid Support	0.03-0.40
T&D Loss Avoidance	0.26-0.64
Avoided Distribution Costs	0.06-0.97
Avoided Transmission Cost	0.01-0.24
Avoided Water Use	0.00-0.26
Value of Fossil Fuel as Price Hedge	0.36-0.96
Avoided Generation Cost	1.28-7.03
Avoided Generation O&M Cost	0.22-0.54
Avoided Generation Capital Cost	1.71-2.31
Total	6.6-20.5 cents/kWh

# Fuel Cells and Transportation

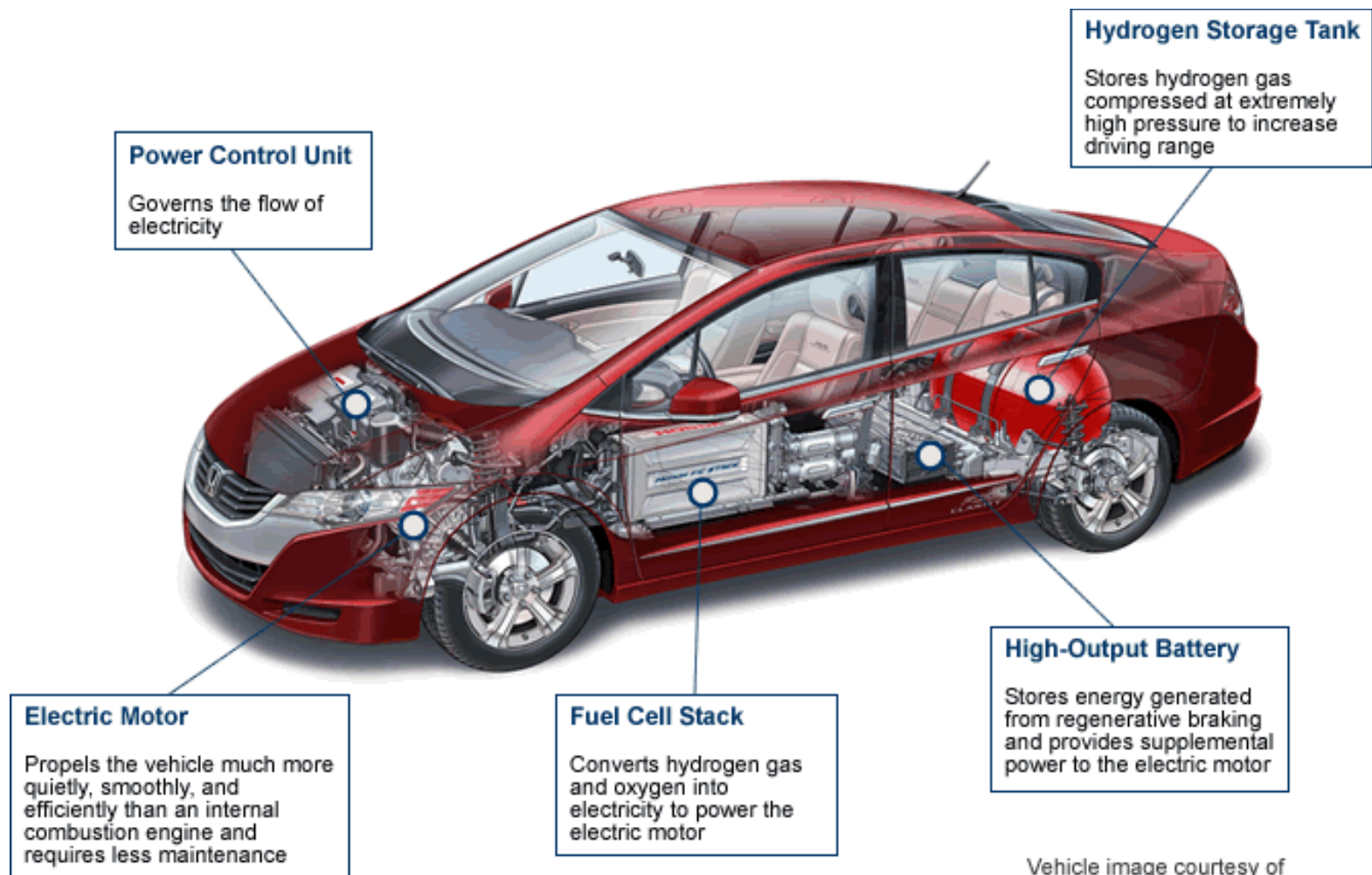
Hydrogen power density 8 times that of batteries –  
*less weight and volume for portability*

- Uranium-235 Higher Density
- Hydrogen
- Gasoline
- Propane
- Natural Gas
- Fat
- Coal
- Wood Lower Density

# Policies Needed for Transportation

- Subsidies for:
  - Infrastructure development
  - Improved hydrogen reformation technology
    - Natural gas steam reforming
    - Methanol
    - Electrolysis
  - Acceleration of PEM cell development
    - Longer hours, cost reduction, impurity tolerance
    - Catalyst replacement
- Regulatory Issues:
  - Hydrogen manufacturing, storage, transportation
  - Emissions regulations
  - Taxing externalities, national security costs

# Fuel Cells In Transportation



Vehicle image courtesy of American Honda Motor Co., Inc.

# Transportation: Infrastructure Problem

- Duplicating existing gasoline filling infrastructure estimated at \$100 billion
  - But do not need every station to carry H<sub>2</sub>
- Can put reformers at gasoline stations – using natural gas to make hydrogen.
  - With current natural gas prices, steam reformation of hydrogen is less expensive than current crude to gasoline processes

# The Future of Fuel Cells

Vijay Vaitheeswaran

- Distributed Generation: HomeGen
  - Onboard processing of natural gas
  - Small units to fit home needs.
- Personal Use: portable power
  - Laptops, cell phones
  - Military applications
- Transportation: Beyond Fossil Fuels
  - Reforming methanol – can get from biomass
  - Reduce dependence on oil
  - Buy in from all the major automobile companies
    - Incumbents usually resist new technologies – but car companies and oil companies alike are investing heavily into the hydrogen economy

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Urban.csuohio.edu

# CSU Energy Policy Center

a.r.thomas99@csuohio.edu



Thank you!