Hydrogen 101

December 19, 2006

SOUTH CAROLINA HYDROGEN AND FUEL CELL ALLIANCE

www.schydrogen.org

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Introduction

The development and commercialization of hydrogen and fuel cell technology is key to our state's future.

Hydrogen can:

- Reduce our reliance on foreign sources of oil and fuel
- Improve the environment
- Spur economic growth
- Increase South Carolina's recognition as a technology innovator and build overall interest

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What is hydrogen?

- Energy carrier not an energy source
- Most abundant element in the universe
- Rarely found in pure form in nature
- Colorless and odorless gas
- Can be produced from hundreds of different sources, many renewable
- Can be converted into an energy source by use of a fuel cell

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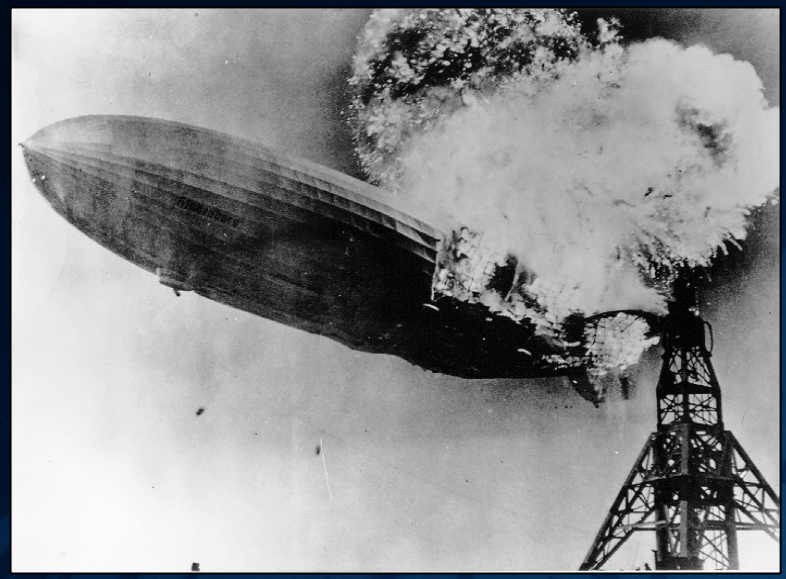
What hydrogen is not…

- Misconceptions
  - Hydrogen is responsible for the explosion of the Hindenburg
  - Hydrogen is more explosive than gasoline
  - Powering a hydrogen car requires a fuel tank almost as large as the car itself
  - Hydrogen is less powerful than gasoline (Actually, Liquid Hydrogen has a BTU of 60,000 per pound and gasoline has a BTU of 18,000)



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Why hydrogen?

Hydrogen is “the forever fuel”

- Petroleum reserves are being depleted and prices susceptible to foreign events beyond our control
- Bio fuels, including ethanol, cannot meet the growing demand of transportation fuels
- Hydrogen cannot be depleted
- Hydrogen has the ability to make societies completely energy-independent

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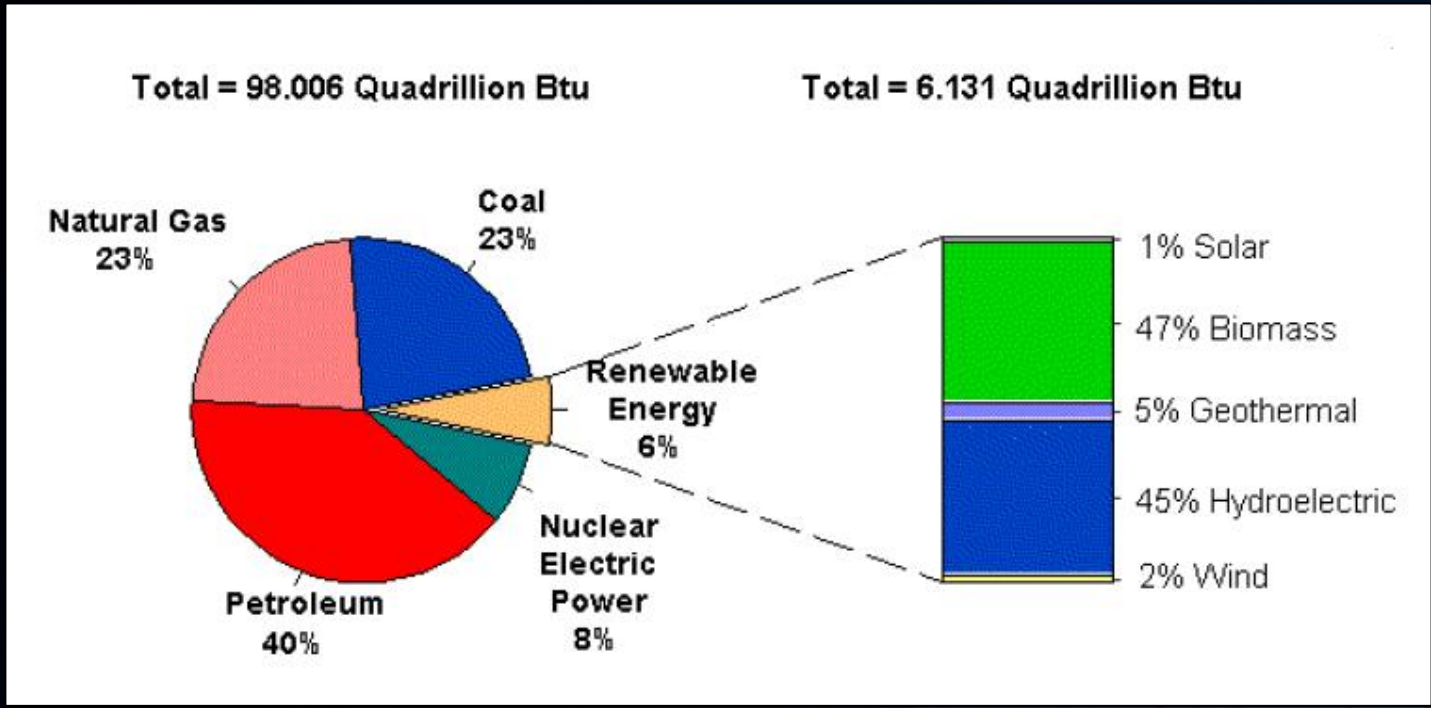
Is Renewable Energy the Answer?



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What are our options?

- Coal and Heavy Hydrocarbons
  - Large environmental signature
  - Global warming concerns
- Renewable energy sources
  - Biomass, Hydro, Wind, Solar
  - May only be partial solution
- Nuclear Fission
  - No new U.S. reactors ordered since 1970's
  - Worldwide renaissance in progress
- Nuclear Fusion - Long-term

Advantages of Hydrogen as an Energy Carrier

- **Inexhaustible**
  - **Can be extracted from water**
- **Clean**
  - **Only emissions from hydrogen fueled car are heat and water**
- **Universally Available to All Countries**
  - **Can be produced with regional energy sources**

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Current Hydrogen Supply Markets

Production Sources

48% Natural Gas

30% Oil

18% Coal

4% Electrolysis of H_20

Major Markets

60% Ammonia/fertilizer

23% Petroleum refining (sulfur removal)

9% Methanol

8% chemical, space and metallurgical processes

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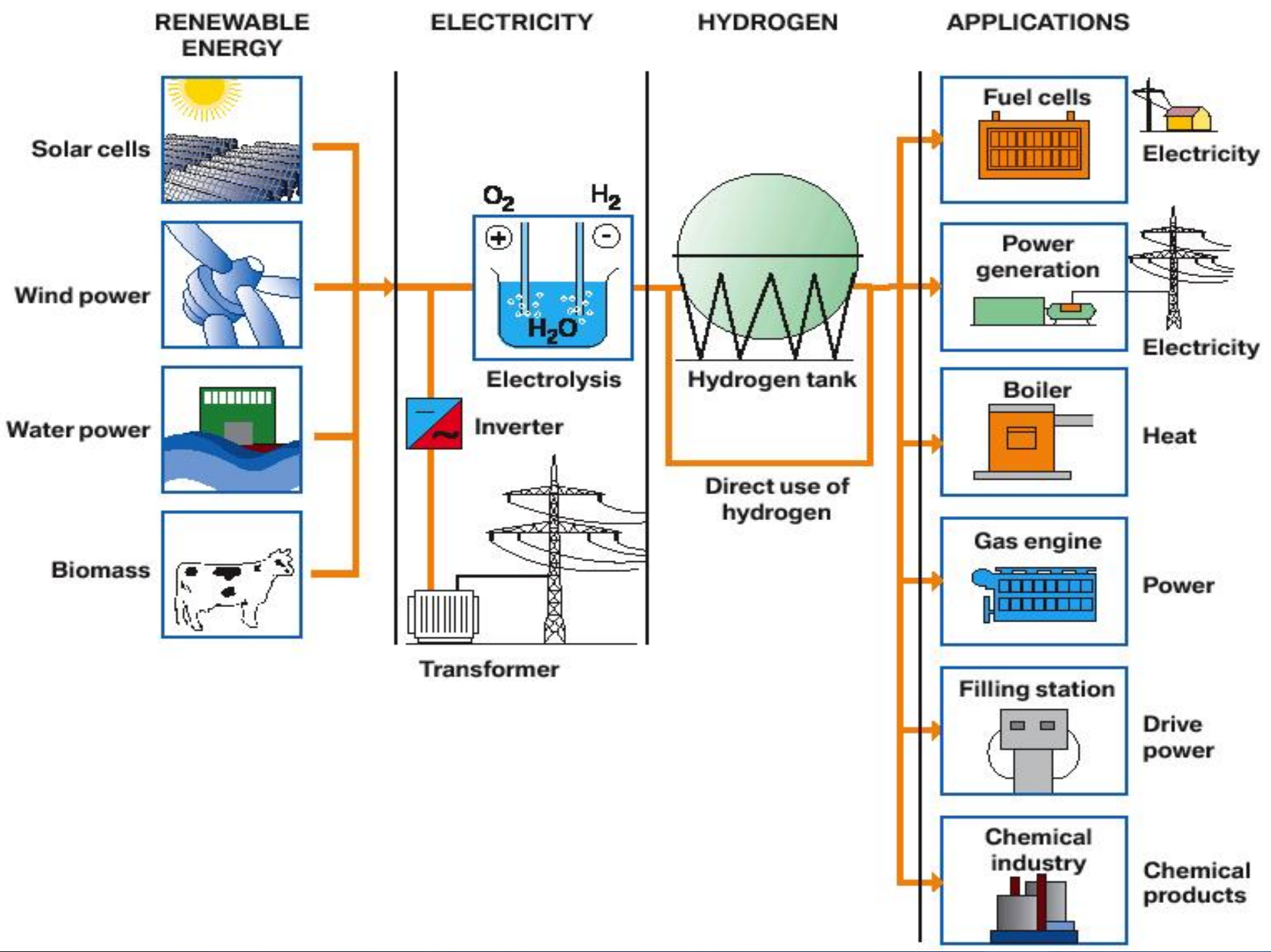
RENEWABLE ENERGY
ELECTRICITY
HYDROGEN
APPLICATIONS
Solar cells
Wind power
Water power
Biomass
O_2
H_2
H_2O
Electrolysis
Inverter
Transformer
Hydrogen tank
Direct use of hydrogen
Fuel cells
Electricity
Power generation
Electricity
Boiler
Heat
Gas engine
Power
Filling station
Drive power
Chemical industry
Chemical products

What is a “Hydrogen Economy”?

- **Broad-based use of hydrogen as a fuel**
  - **Energy carrier analogous to electricity**
  - **Produced from variety of primary energy sources**
  - **Can serve all sectors of the economy: transportation, power, industry, buildings and residential**
  - **Replaces oil and natural gas as the preferred end-use fuel**
  - **Makes renewable and nuclear energy “portable” – transportation needs**

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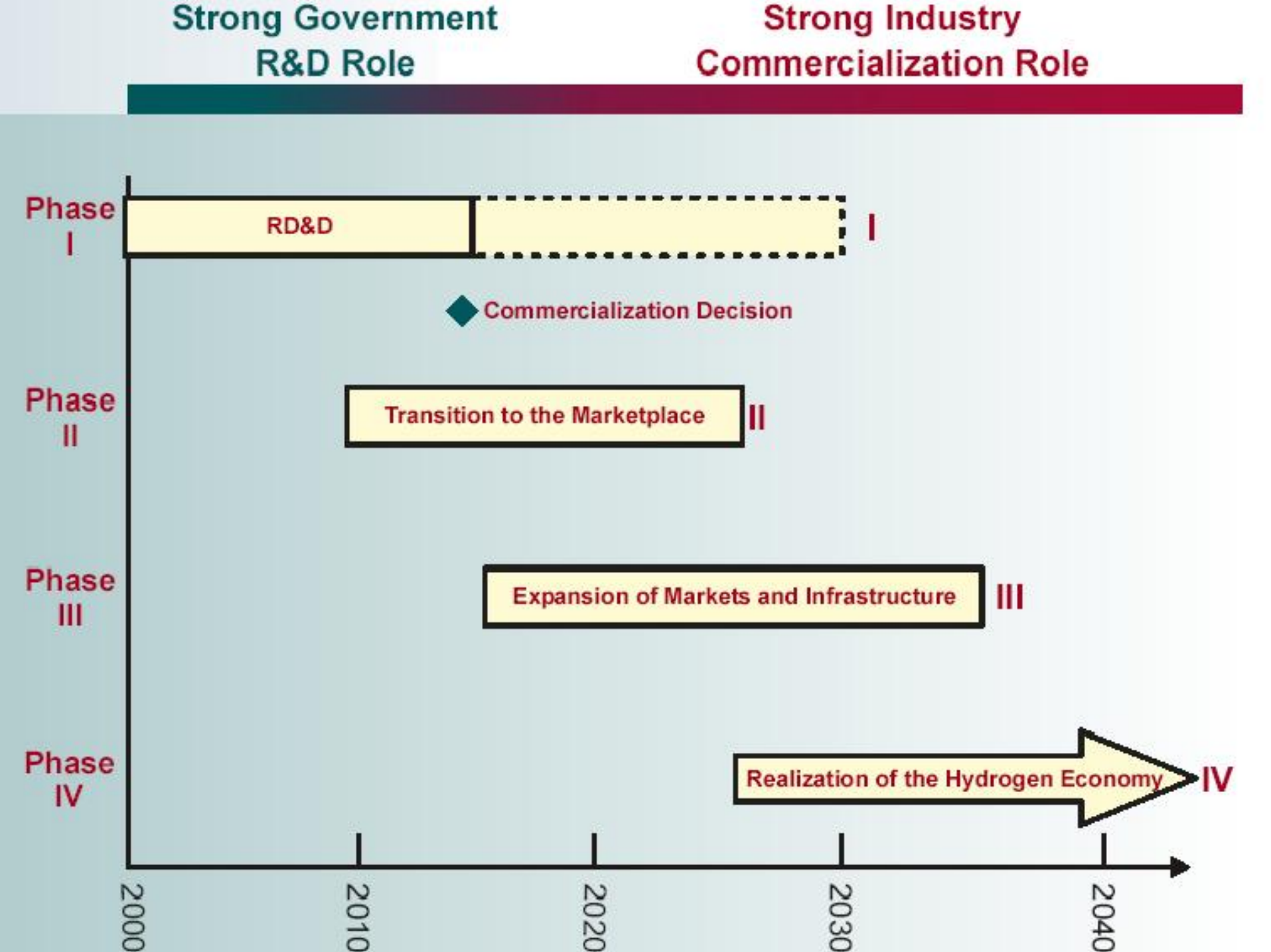
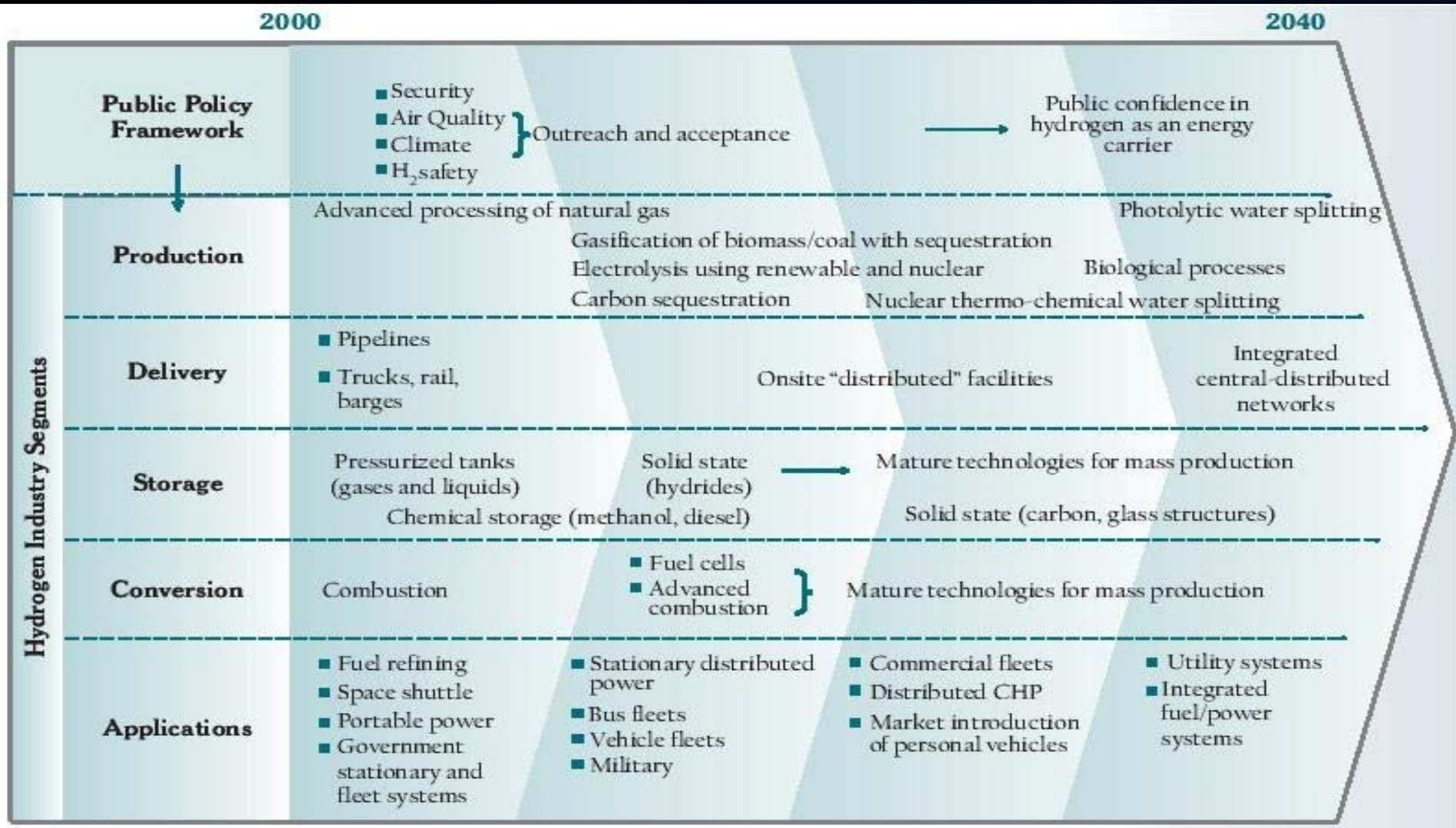

Strong Government
R&D Role
Strong Industry
Commercialization Role
Phase I
RD&D
I
Commercialization Decision
Phase II
Transition to the Marketplace
II
Phase III
Expansion of Markets and Infrastructure
III
Phase IV
Realization of the Hydrogen Economy
IV
2000
2010
2020
2030
2040

Timeline for Hydrogen Industry Segments



What is a fuel cell?

- Produces electricity
- Power source similar to a battery
- Requires refueling, not recharging
- Heat and water are the only emissions of hydrogen fuel cell powered vehicles
- Can be used to power homes, businesses, vehicles and small portable devices

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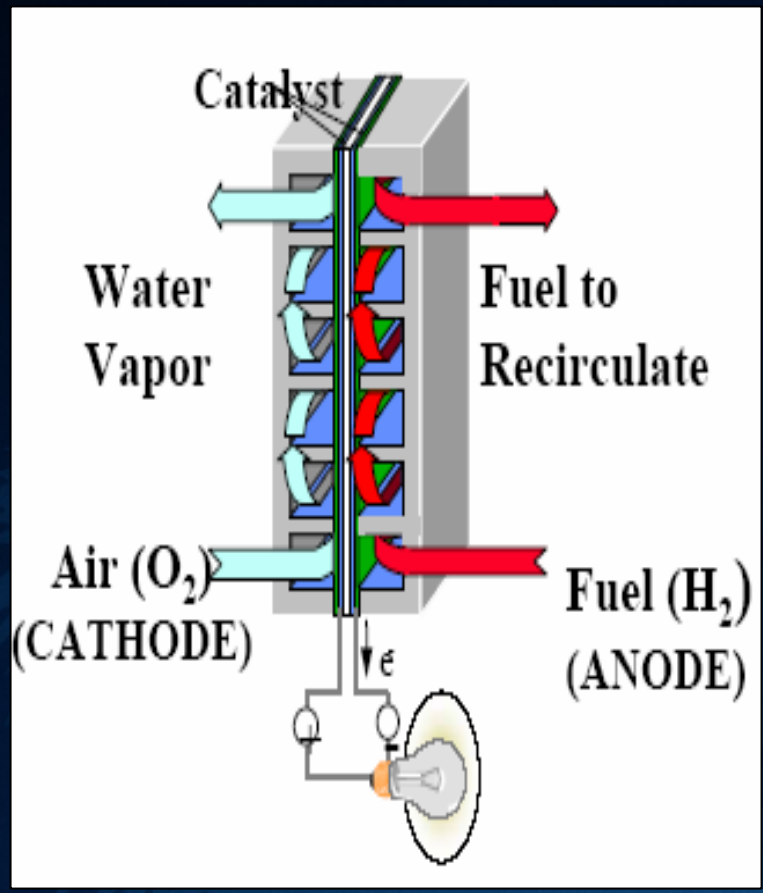
Fuel Cell Basics

- "Hydrogen Fueled Battery" Invented by Sir William Grove in 1839
- Reacts H2and O2 electrochemically
- First practical use by NASA in 1960's space program
- Operates continuously when supplied with H2fuel
- Byproduct is pure water/ High Efficiency (55-60%)



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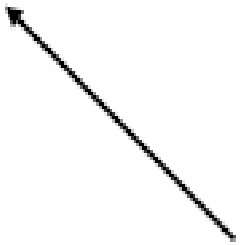
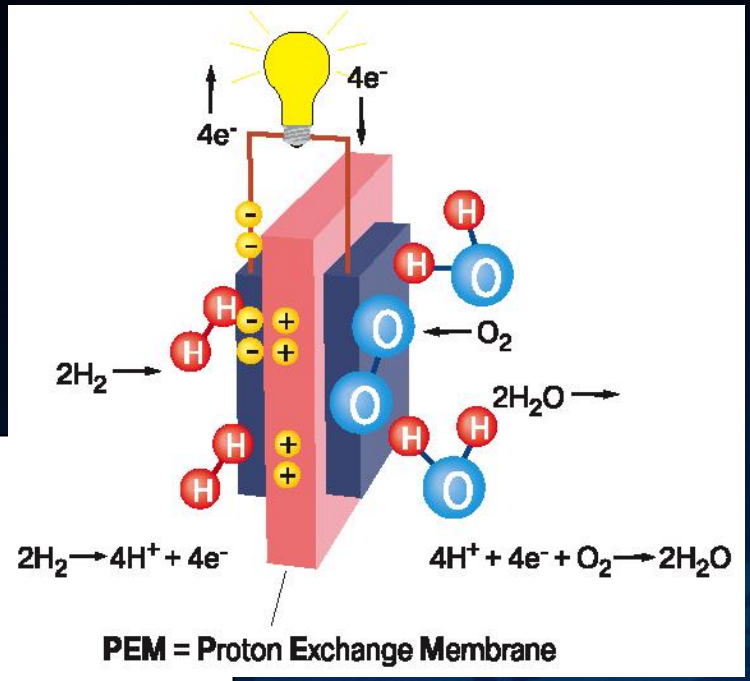
Types of Fuel Cells

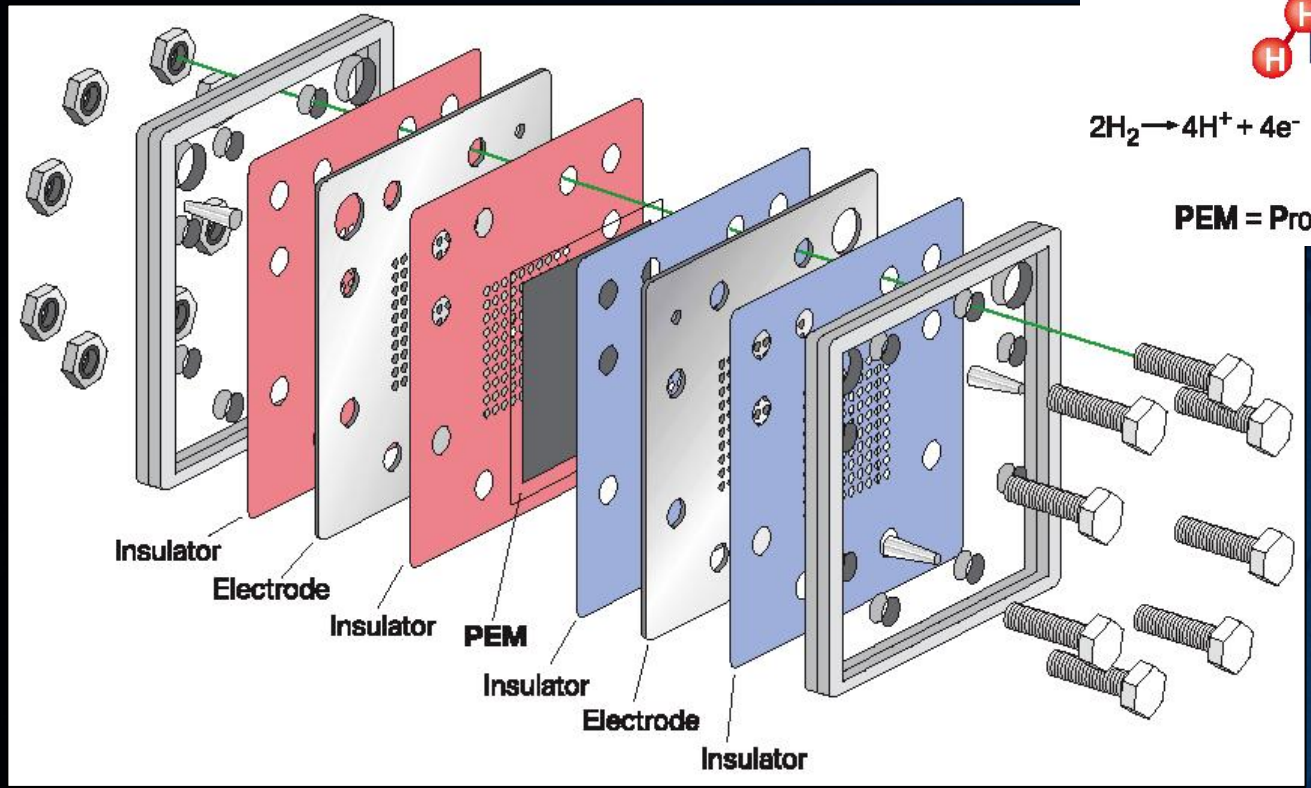
Fuel Cell Type	Electrolyte	Temperature	Application
Alkaline	potassium hydroxide	120 °C	space, transport
Phos Acid	phosphoric acid	200	power, transport
Molten Carbonate	Li & K carbonate	650	stationary power
Solid Oxide	stabilized zirconia	800-1,000	stationary power
PEM	solid polymer	80	space, transport, stationary power



Most commonly used in vehicles

Fuel cell structure





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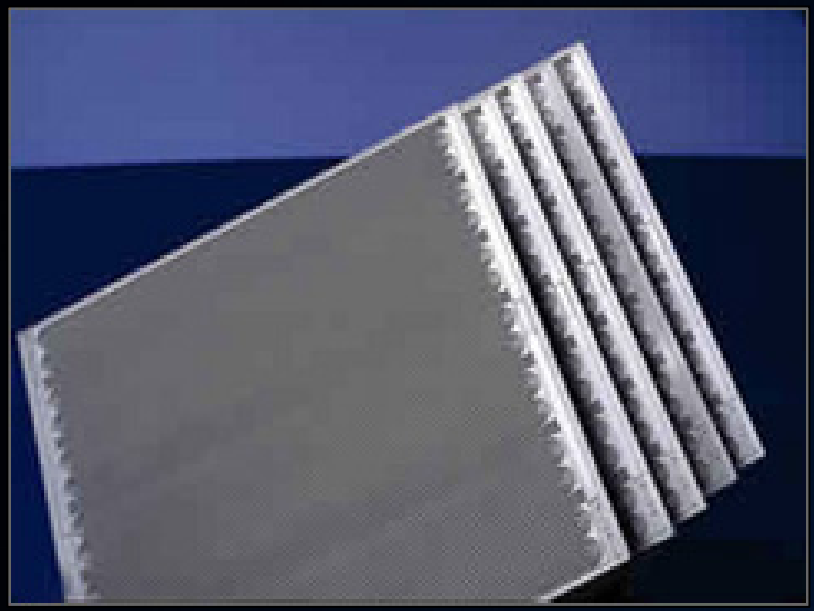
Fuel Cell Power Systems



PEM Fuel Cell Plates

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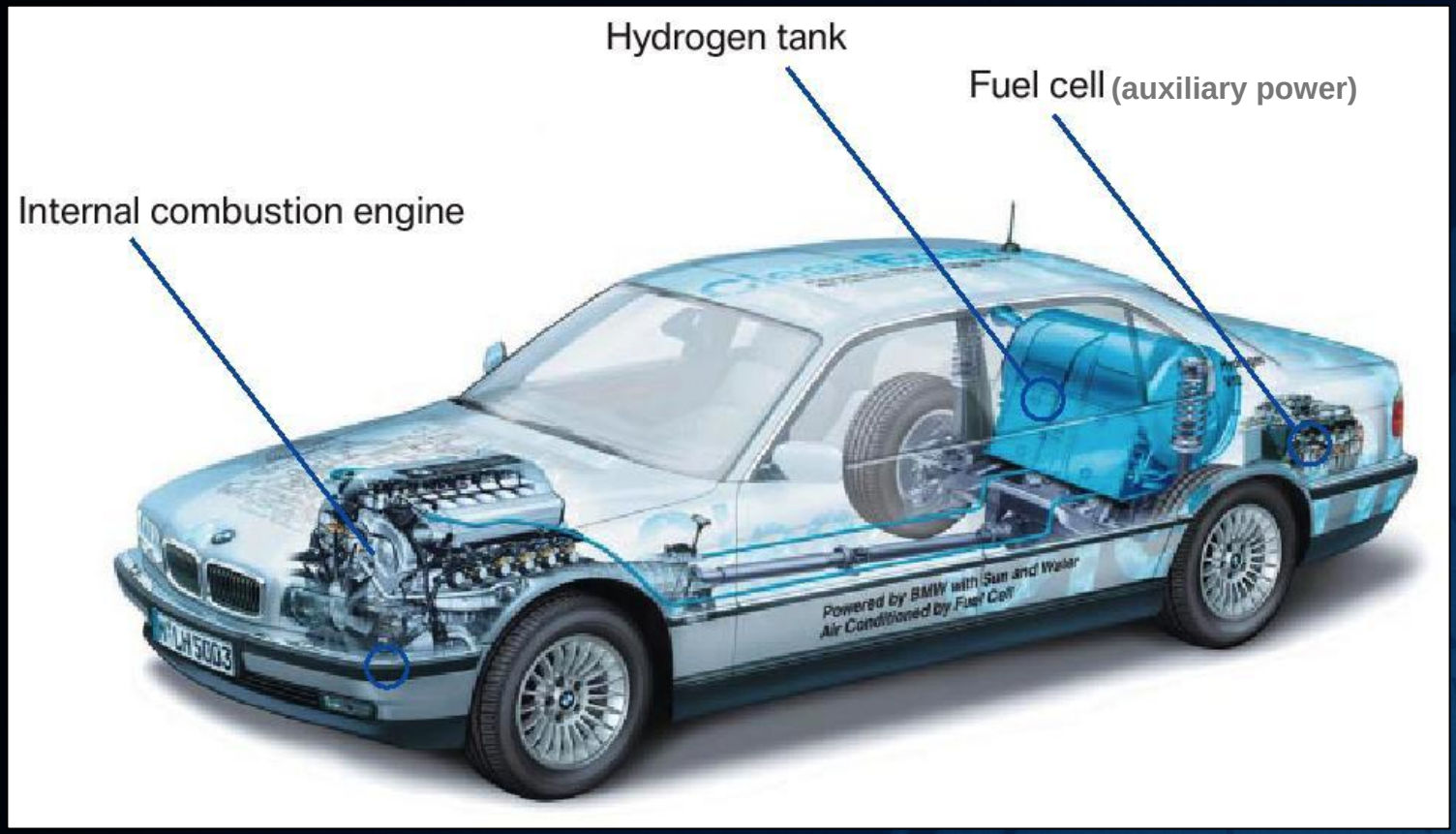
Hydrogen powered Internal Combustion Engine (ICE)



BMW 7 Series

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Hydrogen ICE Vehicles

BMW 7 Series

Ford Model U

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Hydrogen Fuel Cell Vehicles

General Motors Hydrogen Fuel Cell Car

Toyota HFCV SUV

Hydrogen Refueling Infrastructure

Shell Hydrogen and Gas Station

Washington, D.C.

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Hydrogen Refueling Infrastructure

BP Hydrogen Station

Los Angeles, CA

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Stationary Power Development

GM Home Power Unit

Ballard 1kW Stationary Fuel Cell System

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Stationary Power Development

Avista Labs SR72
PEM Fuel Cell

Honda Home Hydrogen
Generation System

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Miscellaneous Power Systems

John Deere 20kW Pro Gator

ENV Motorcycles Hydrogen Powered Bike

Ballard Hydrogen powered laptop

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Why now?

There is an emerging hydrogen economy which provides a unique opportunity for South Carolina

- Industrial demand is increasing
- Hydrogen market is growing by more than 10% every year
- Economic opportunities in production, storage, distribution and commercialization will continue to be created
- Government investments are increasing

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National Commitment to Hydrogen Technology

"Tonight I'm proposing $1.2 billion in research funding so that America can lead the world in developing clean, hydrogen-powered automobiles…With a new national commitment, our scientists and engineers will overcome obstacles to taking these cars from laboratory to showroom, so that the first car driven by a child born today could be powered by hydrogen, and pollution-free."

President Bush
January 28, 2003,
State of the Union Address

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Why South Carolina?

SC is one of only 14 states with a hydrogen roadmap, plan or coordinated effort

SC has a strong hydrogen R&D base

- Savannah River National Laboratory – Research in hydrogen storage and production
- Center for Hydrogen Research – Opened in Feb. 2006 with shared hydrogen research labs for academic and industrial research partners. Toyota invested approx. $1 million in the lab in Sept '05

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Why South Carolina? (cont)

- University of South Carolina's NSF funded Industry/University Cooperative Research Center for Fuel Cells Research
- South Carolina State University's Clyburn Transportation Center – Research in transportation and education
- Clemson University International Center for Automotive Research – Research in automotive design and integration

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Why South Carolina? (cont)

Strong hydrogen-related business clusters

- BMW – Announced plans to mass produce hydrogen cars by 2010, has R&D facilities in Greenville, production in Spartanburg
- GE Energy – Greenville location works closely with fuel cell development
- Washington Savannah River Company – A world leader in the management and storage of hydrogen for defense programs

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South Carolina Hydrogen and Fuel Cell Alliance

- Dedicated to developing and promoting hydrogen initiatives that focus on long-term growth for South Carolina
- Founded in January 2006 from six core organizations:
  - South Carolina Department of Commerce
  - University of South Carolina
  - Clemson University
  - South Carolina State University
  - Savannah River National Laboratory
  - Center for Hydrogen Research

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Commerce's Role

- Provide administrative support
- House offices of Executive Director and Administrative Assistant for SCHFCA
- Approximately $500,000 in Alliance funding flows through Commerce
- Support recruiting efforts to attract hydrogen/fuel cell related research and businesses to the state.

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Alliance Activities

- Hosting 2009 National Hydrogen Association in Columbia
- Participating in Fuel Cell Seminar and 2007 NHA Conferences
- Will hire Executive Director by January 2007
- Hosting 2007-2008 NHA H2U Student Design Competition

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Alliance Activities (cont.)

- Currently drafting hydrogen-friendly legislation and incentives for South Carolina
- Ongoing relationships with other state hydrogen initiatives for future collaborations

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Recent SC Accomplishments

- The Greater Columbia Fuel Cell Challenge
  - Six awards totaling more than $150,000 for fuel cell projects around Columbia
    - Backup power at Benedict College
    - A hands-on exhibit at EdVenture Children's Museum
    - Segway Personal Transporters for USC campus
    - Extended power packs for Columbia Law Enforcement
    - Citizen's school for hydrogen and fuel cell technology
    - Portable batteries for ETV cameras

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Recent SC Accomplishments (cont)

- Federal Transit Administration Selects SC for Hydrogen Bus Program Awards
  - Eleven companies were selected to receive a portion of $43.5 million for hydrogen programs
  - USC and SCRA have a $5.67 million project to bring the first fuel cell bus to South Carolina in time for the NHA's Annual Hydrogen Conference

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Major National and International Players

Equipment Suppliers

- Air Products and Chemicals, Inc.
- Air Liquide America
- Praxair, Inc.
- Proton Energy

Energy Companies

- Shell Hydrogen
- BP
- Chevron Technologies
- *Linde AG

* Indicates a presence within South Carolina

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Major National and International Players

OEMs

- Plug Power
- UTC Power
- Ballard Power Systems
- *Millennium Cell

Auto Companies

- *Toyota Motor Sales
- *BMW America
- *American Honda Motor Company
- Ford
- *General Motors

* Indicates a presence within South Carolina

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Current Challenges

- No hydrogen-friendly legislation
- Public is under-educated on the benefits of hydrogen energy and economies
- No state-supported hydrogen demonstrations
- No attractive hydrogen-based state business packages
- No firm hydrogen infrastructure

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Available Resources

- **South Carolina Council on Competitiveness** – Currently forming a Fuel Cells Cluster Committee
- **EngenuitySC** – Promotes knowledge-oriented companies in South Carolina
- **USC Columbia Fuel Cell Collaborative** – Promotes recruiting and retaining world-class innovators in hydrogen and fuel cell economies

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Available Business Partnerships

USC's Innovista District

- Unique research district with widely available property for housing, work, retail and educational benefits. Location planned for riverfront property in Columbia, SC.

Center for Hydrogen Research

- Lab spaces available to lease to industry and commercial researchers. Toyota has already invested $1 million.

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Available Partnerships (cont)

SC Launch! (An SCRA collaboration)

- Provides mix of incentives, seed funding and loans to entrepreneurs to drive innovation, jobs and economic development in SC. Targets companies with high potential to locate in South Carolina.

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Hydrogen's Potential

- U.S. market expected to exceed $1 trillion and one million jobs by 2020
- Hydrogen and fuel cell job potential for SC and surrounding communities is 40,000
- Potential $10 billion in capital investment by 2020
- Could build healthy in-state competition for hydrogen research and production
- Would create higher paying jobs

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How to Capitalize

- Need to expand existing market
- Promote framework for success and sustainability through long-term payback period
- Collaborations between universities and private researchers can bring in large industrial developments
- Make SC's advantages known to government, industry and public

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Resource contacts

- Todd Wright – Savannah River National Lab
- John Van Zee – USC Center for Fuel Cells
- Chris Przirembel – Clemson CU-ICAR
- Fred Humes – Center for Hydrogen Research, Economic Development Partnership

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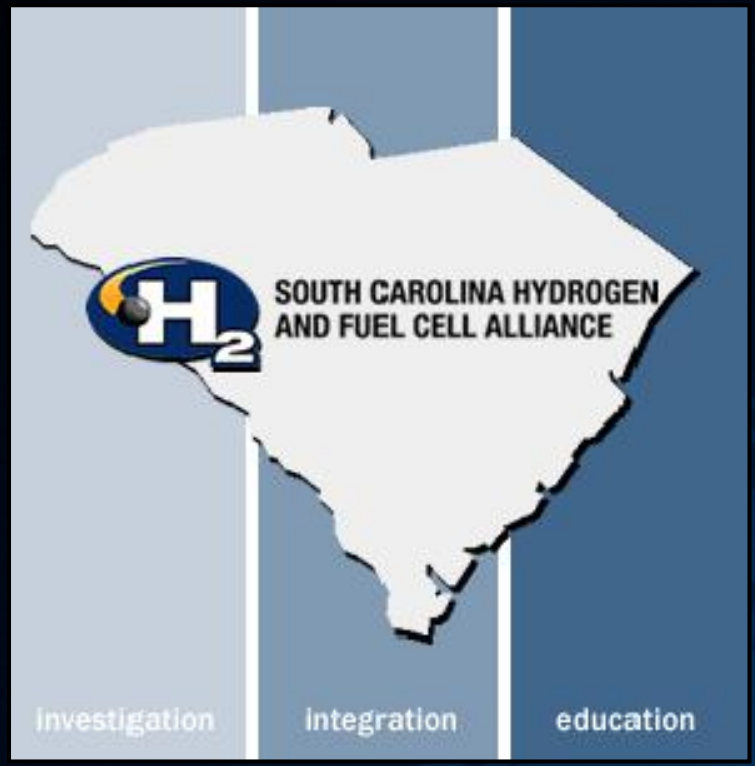

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