Fuel Cells 101

Hydrogen Fuel Cell Educational Outreach Workshop

Presented by David Cooke

October 21st, 2013

The Ohio State University

OHIO energy PROJECT

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Canadian Hydrogen and Fuel Cell Association

Why are hydrogen and fuel cells important?

- Hydrogen and fuel cells are technology solutions that are part of an integrated and sustainable energy system for future generations

- Continued innovation in this sector advances national objectives of:
  - Economic development and job creation
  - Enhancing Canada's science and technology capacity
  - Clean air (eliminates NO_x, SO_x, CO and particulates)
  - Greenhouse gas emission reduction
  - Reducing the carbon impact of Canada's oil and gas resources

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The Need For Energy

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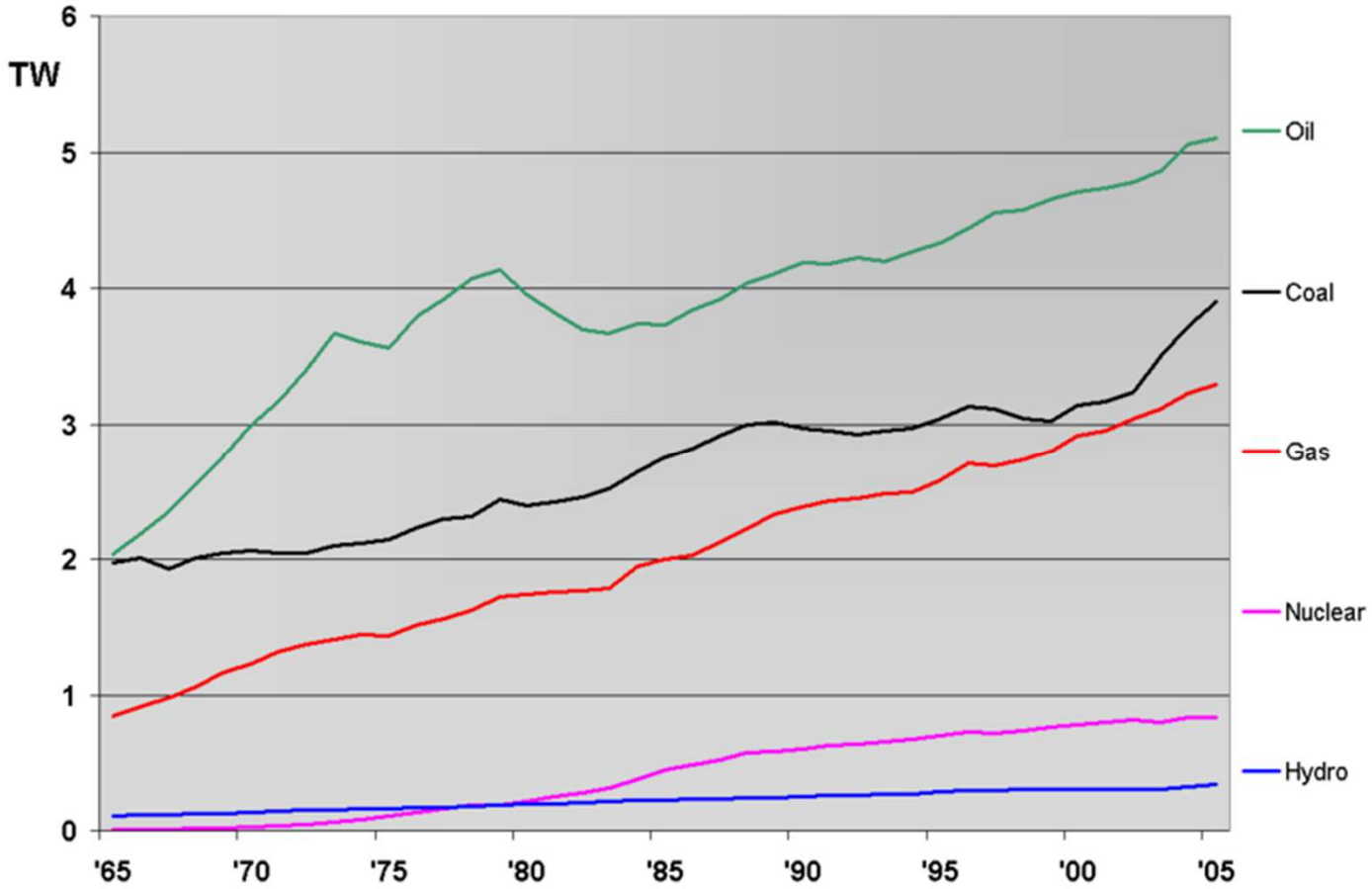
World Annual Energy Consumption in Terrawatts



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How Can the Demand Be Met?

- Energy From Fossil Fuels
- Nuclear Energy
- Conservation and Efficiency
- Renewable Energy

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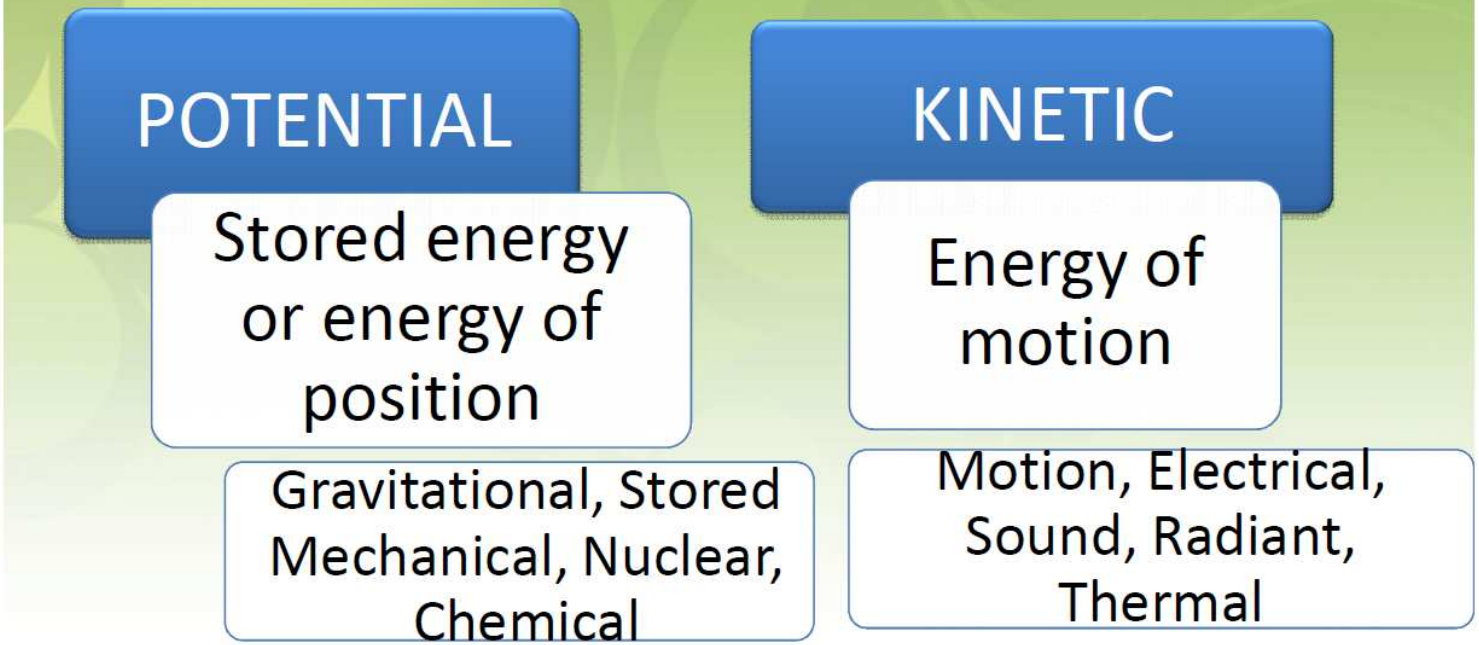
What is energy?

- Ability to do work or cause change
- Produces Warmth
- Produces Light
- Produces Sound
- Produces Movement
- Produces Growth
- Powers Technology

Classes of Energy



Potential Energy

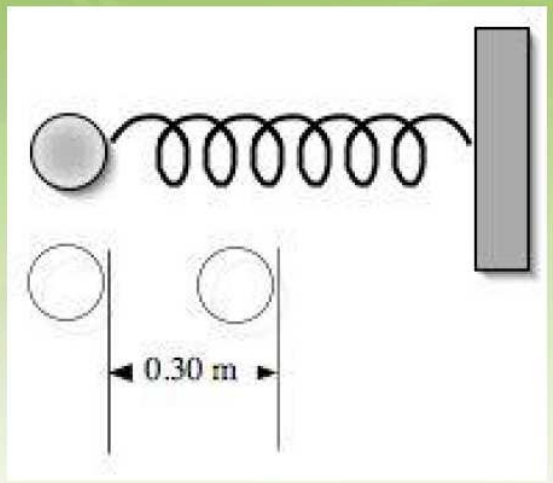
Gravitational Energy
– energy an object or substance has because of its position

Anything “up high”

Potential Energy

Stored Mechanical Energy – stored in an object by the application of force

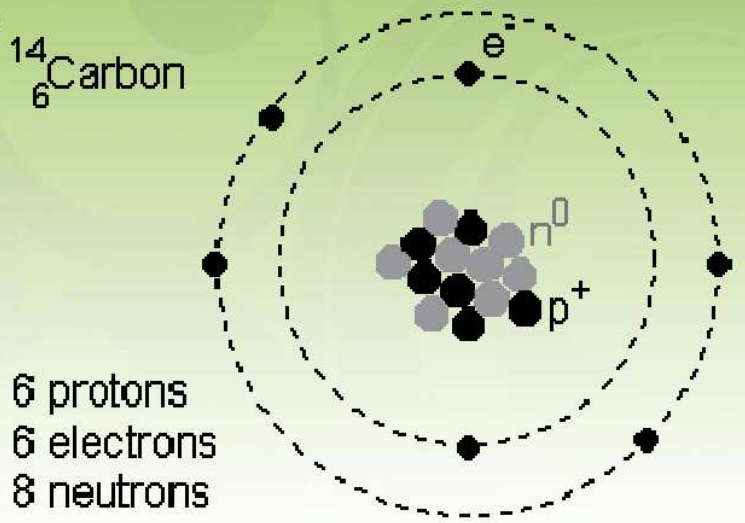
Must push or pull on an object



Potential Energy

Nuclear Energy – energy stored in the nucleus of an atom

Holds the atom together



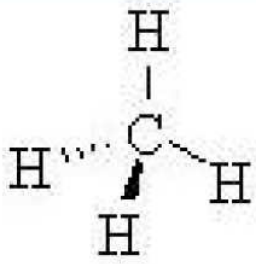
Potential Energy

Chemical Energy – energy stored in the bonds between atoms

Holds molecules together

CH_4

Molecular Formula



Perspective Drawing

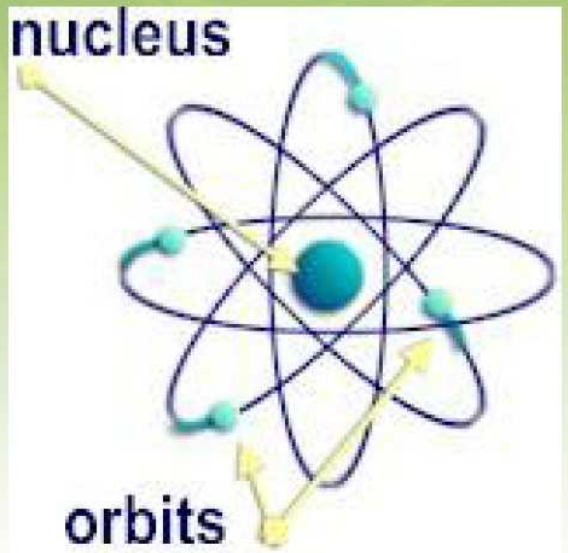
Kinetic Energy

Mechanical (Motion) Energy – movement of objects or substances from one place to another

Kinetic Energy

Electrical Energy
– movement of electrons

NOT AN ELECTRON PARADE!

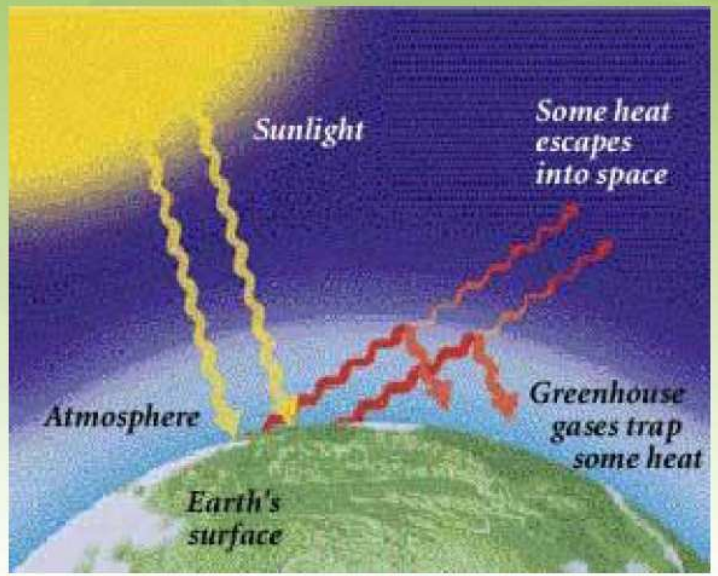


Kinetic Energy

Sound Energy
– movement of energy through substances in the form of longitudinal/compression waves

Kinetic Energy

Radiant Energy – electromagnetic energy that travels in transverse waves



Kinetic Energy

Thermal (Heat) Energy – internal energy of a substance due to the vibration of atoms and molecules making up the substance

Energy Transfers

1 – Energy can not be created nor destroyed, only changed.

- Law of Conservation of Energy
- First Law of Thermodynamics

2 – Energy will always transfer from high to low.

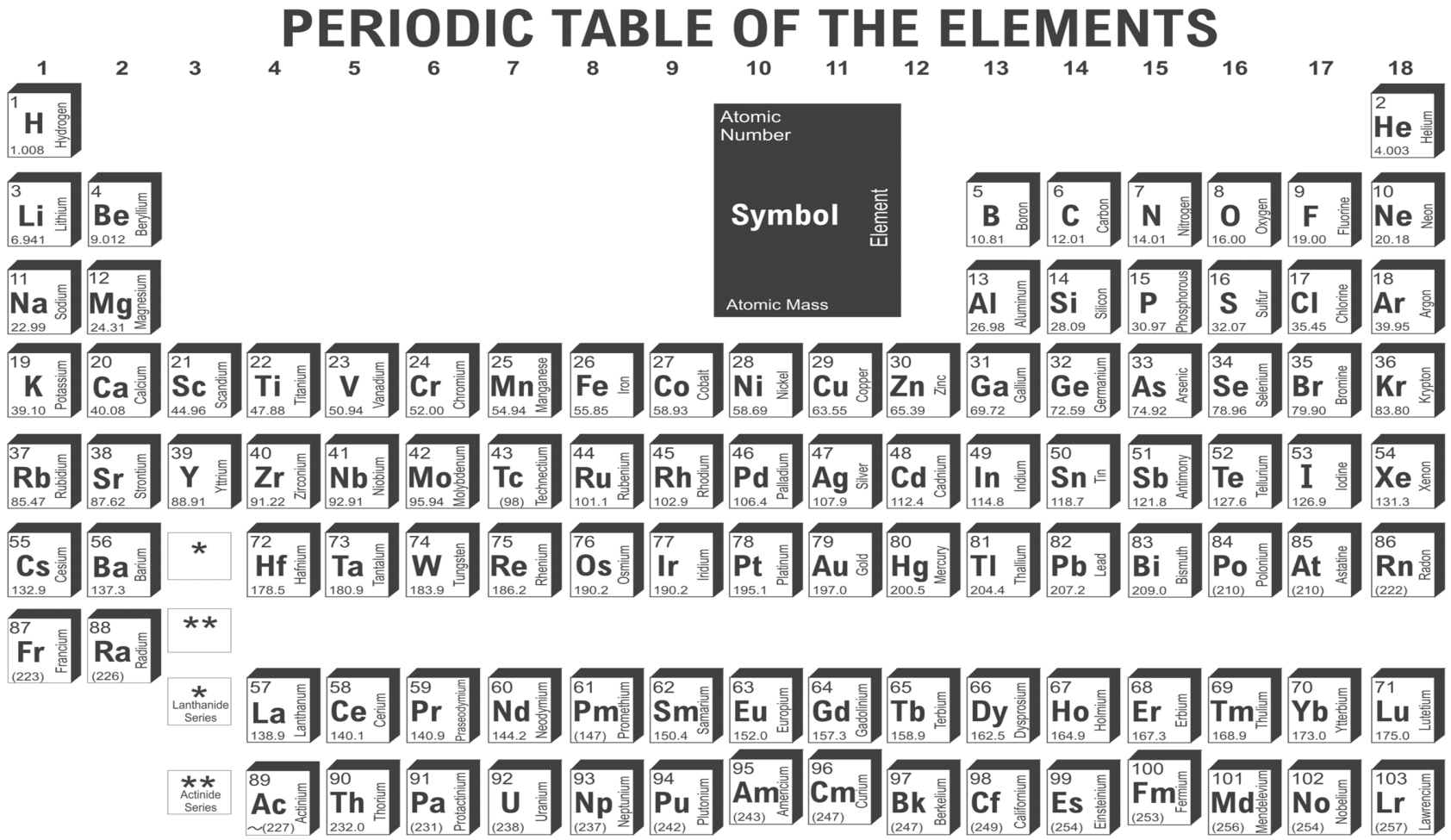
3 – No energy transfer is 100% efficient.

Hydrogen Basics

- Hydrogen is the universe's most common and simplest element.
- As a fuel it provides benefits to energy security, the environment and economic growth.
- Consisting of one proton and one electron, on earth it is found bonded to other elements (for example, when combined with oxygen, it forms water - H_2O).

- The global hydrogen industry is well established and produces 50 million tons of hydrogen per year.
- Can be produced from fossil fuel-based feedstocks such as natural gas.
- Can be produced from off-peak electricity from nuclear, solar, wind, tidal energy sources.
- Can store off-peak energy produced by renewable energy technologies such as solar, wind and tidal generation.

Hydrogen Basics



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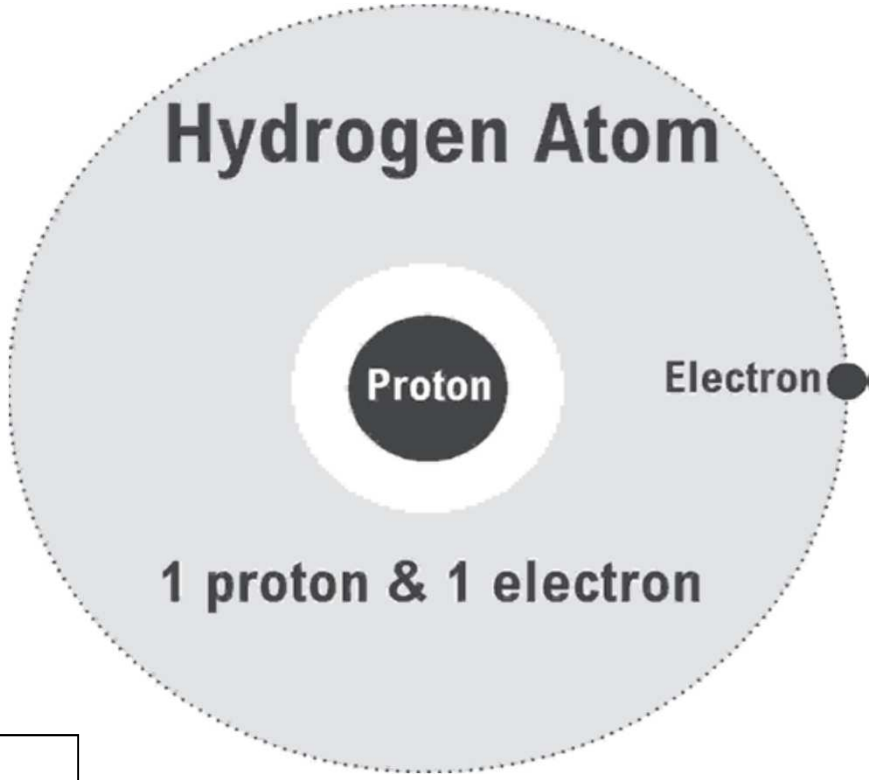
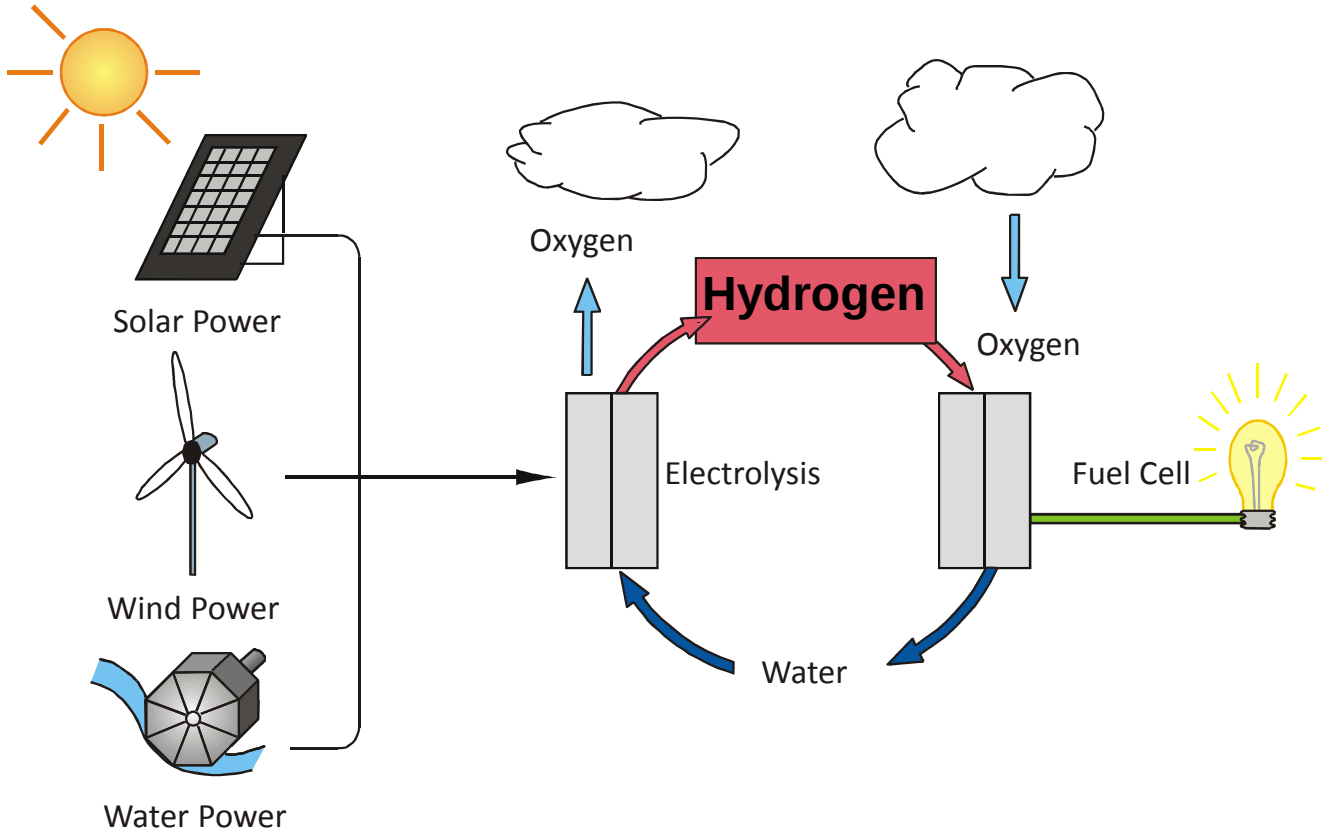
Hydrogen Basics

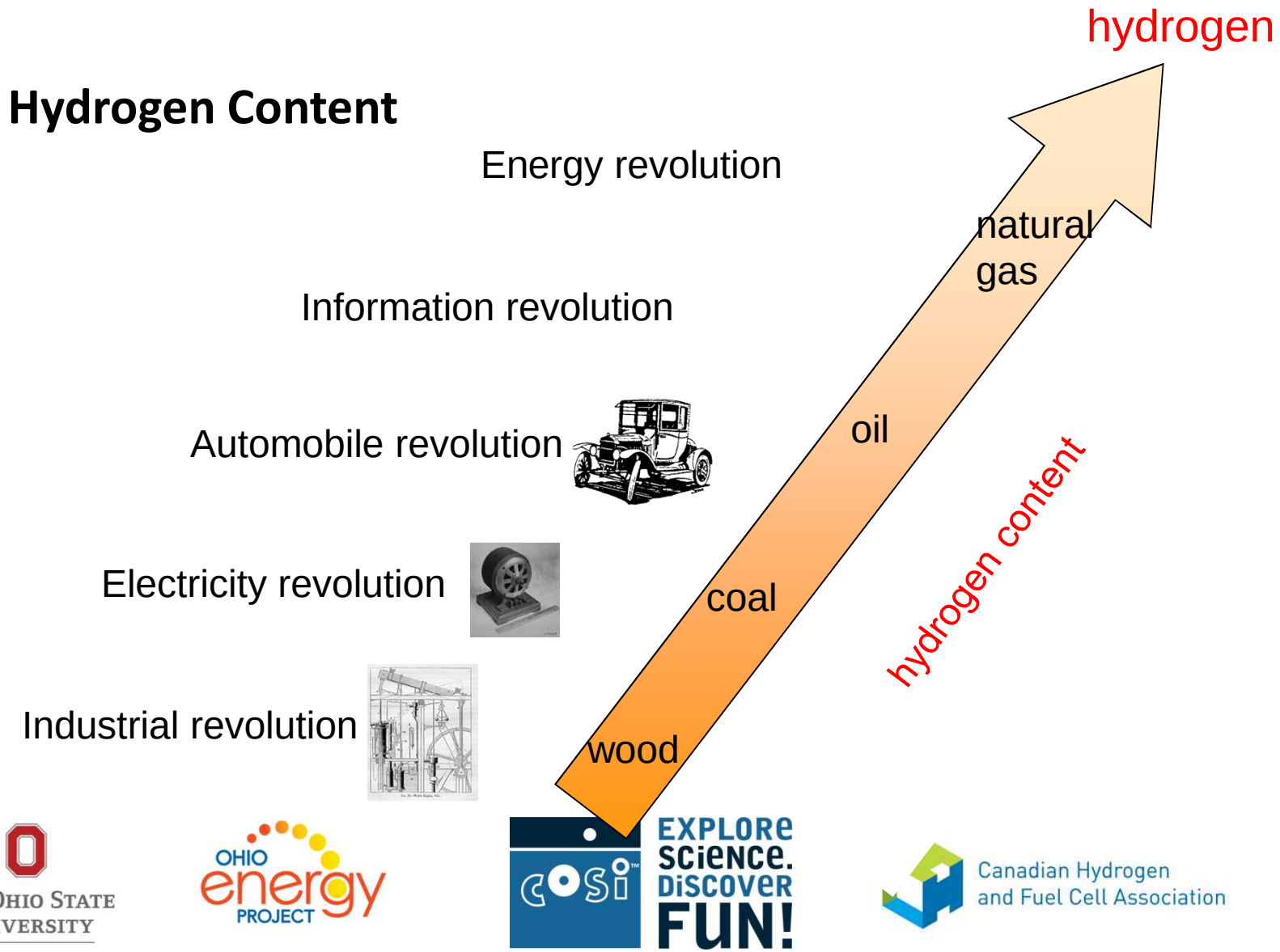


Protons have a + charge
Electrons have a - charge

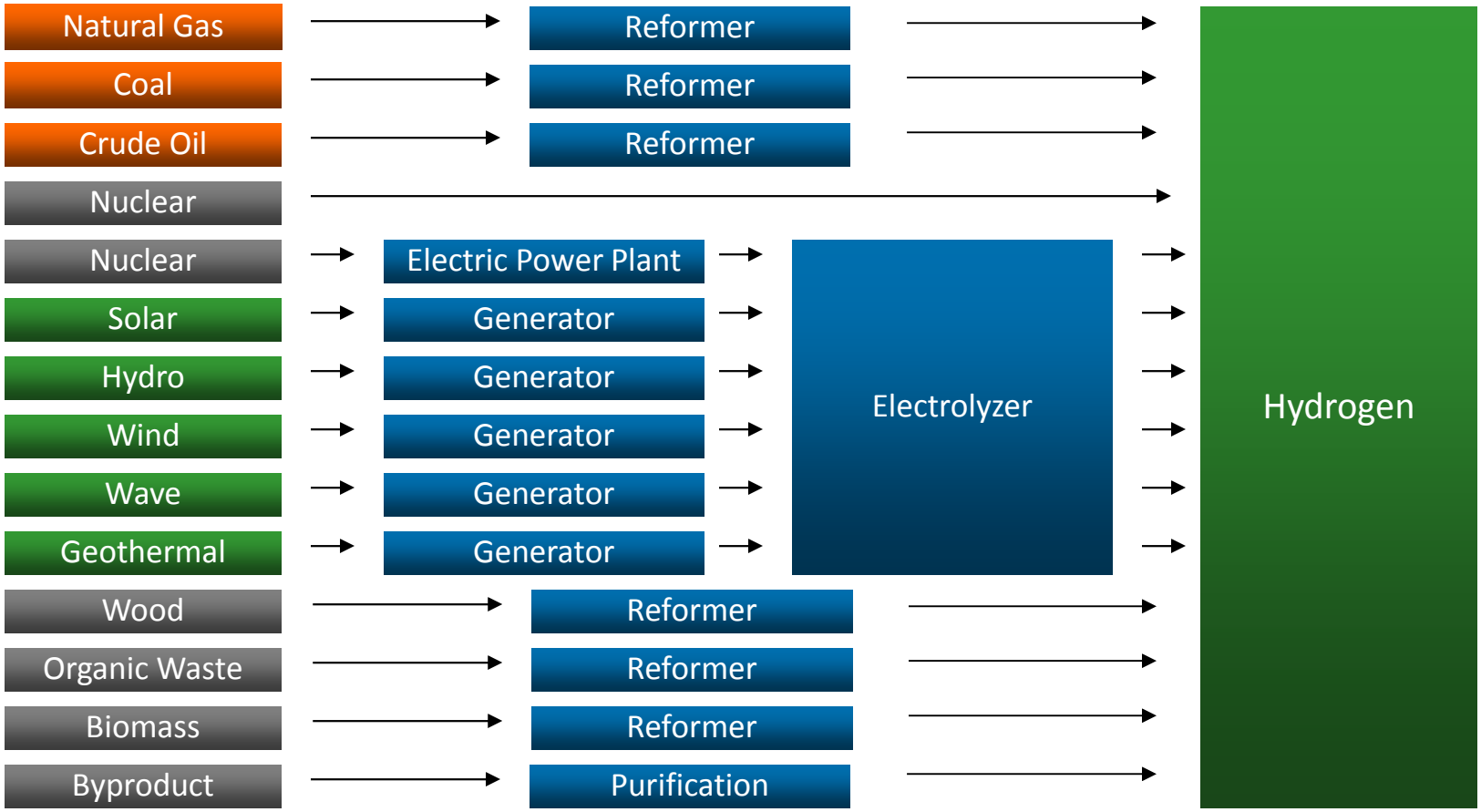
Where does hydrogen come from?



Hydrogen Through The Years



Hydrogen is a safe, efficient energy carrier that can be produced from multiple feedstocks



Note: Canada safely produces 3 million tonnes of hydrogen per year

Hydrogen – Energy Storage

- Energy Storage Will be a Focus of Future Energy Systems

The Fuel Cell

- The invention is more than 150 years old

Electrolyzer

Grove's gas battery
(First Fuel Cell, 1839)

What is a fuel cell?

- An electrochemical device that enables the chemical energy of a variety of fuels to be converted directly into electricity

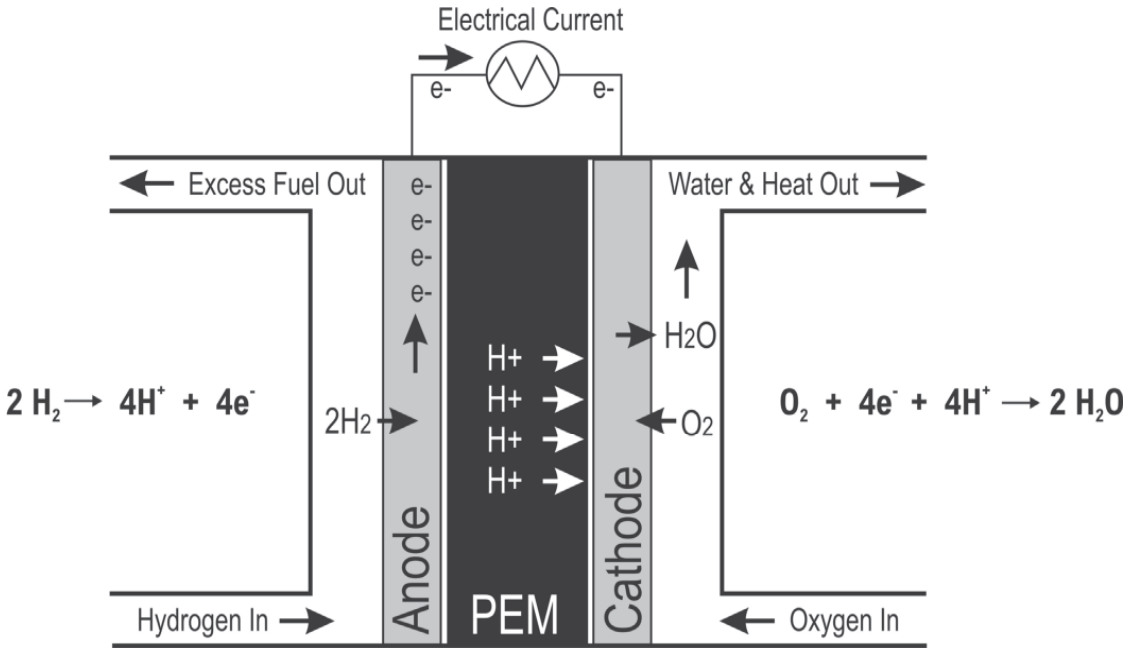
Benefits:

- Superior energy efficiency
- Multiple feedstocks: hydrogen, methanol, natural gas, formic acid, ethanol
- Zero to near-zero emissions
- Versatility – can be utilized in micro, portable, stationary, and mobile power applications
- Low maintenance costs, quiet operation, flexibility for innovative designs

What is a fuel cell?

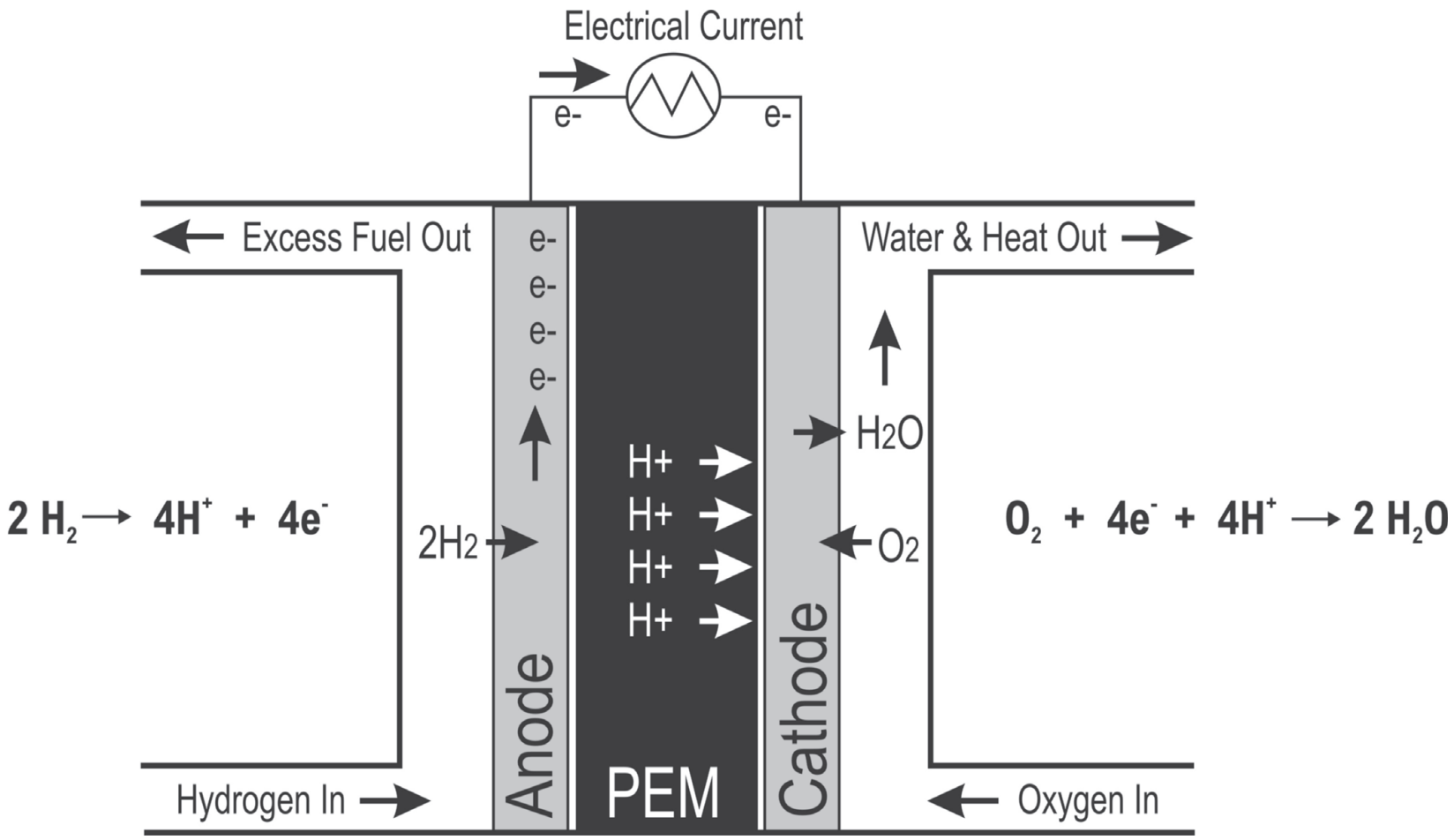
How a Fuel Cell Works

- A fuel cell consists of two electrodes, the anode and the cathode, separated by a proton exchange membrane (PEM).
- Hydrogen is blown over the anode and oxygen (from air) over the cathode.
- When hydrogen reaches the catalyst layer, it separates into protons (hydrogen ions) and electrons.
- The electrons freed at the anode, are conducted in the form of an electric current through the external circuit.
- At the cathode, oxygen from the air, electrons from the external circuit and protons combine to form water and heat.



Courtesy of Ballard Power

How a Fuel Cell Works



Hydrogen and fuel cells enable clean energy systems

- They reduce the carbon impact of fossil fuels and supplement the intermittent nature of renewable energy sources.

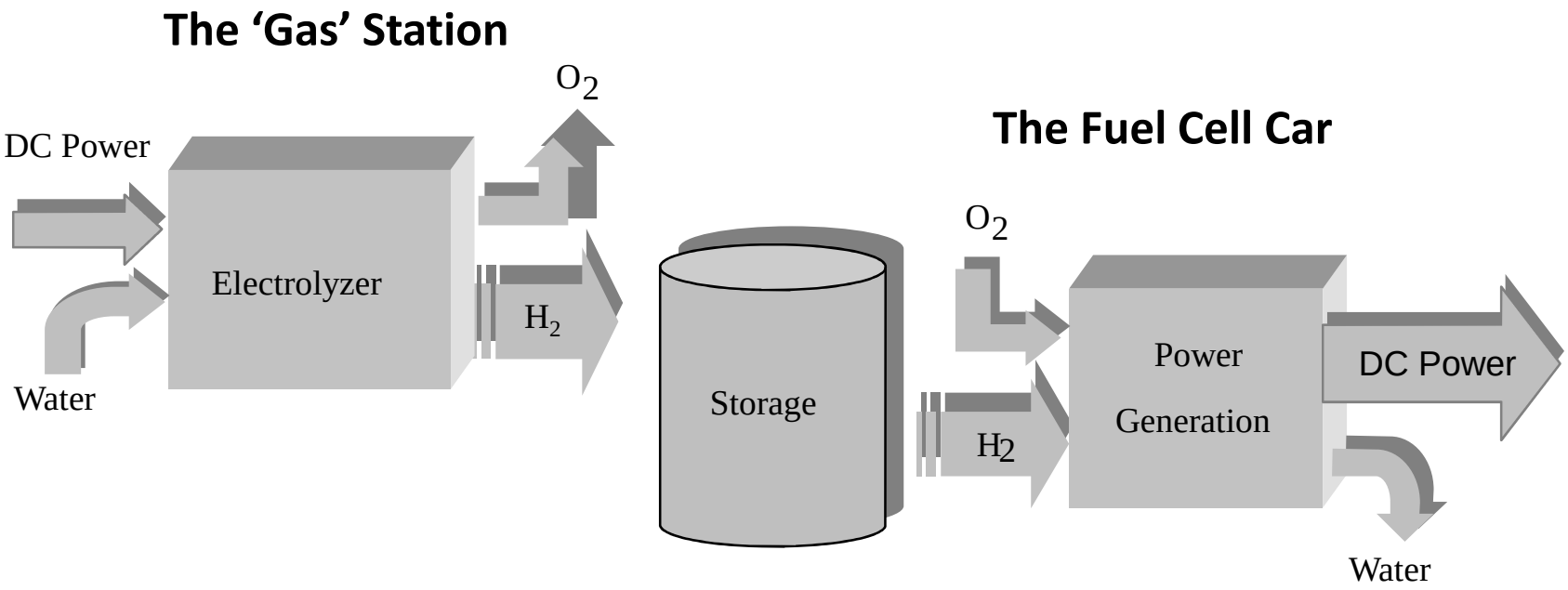
Hands-On with a Fuel Cell Model Car

- Most of the concepts that explain the basics of a solar power, hydrogen and fuel cells are covered with standard curriculum topics
- We will be using the Heliocentris Dr FuelCell Model Car – A Curriculum based product focussed on teaching the science behind solar hydrogen fuel cells
  - Product is focussed on teaching the science curriculum
- Designed for schools specifically
- Known for Quality & Durability
- Yours to keep after the workshop

What will we learn in the investigation?

- How to produce hydrogen using solar energy
- How to store hydrogen
- How to use the hydrogen we have produced to run a fuel cell car
- Some hydrogen fuel cell background

A Hydrogen System for a Fuel Cell Car



A Hydrogen Fuel Cell Car

Photo and Illustration by DaimlerChrysler 2004