



## Fuel Cells 101

### Hydrogen Fuel Cell Educational Outreach Workshop

Presented by David Cooke

October 21<sup>st</sup>, 2013



## Why are hydrogen and fuel cells important?

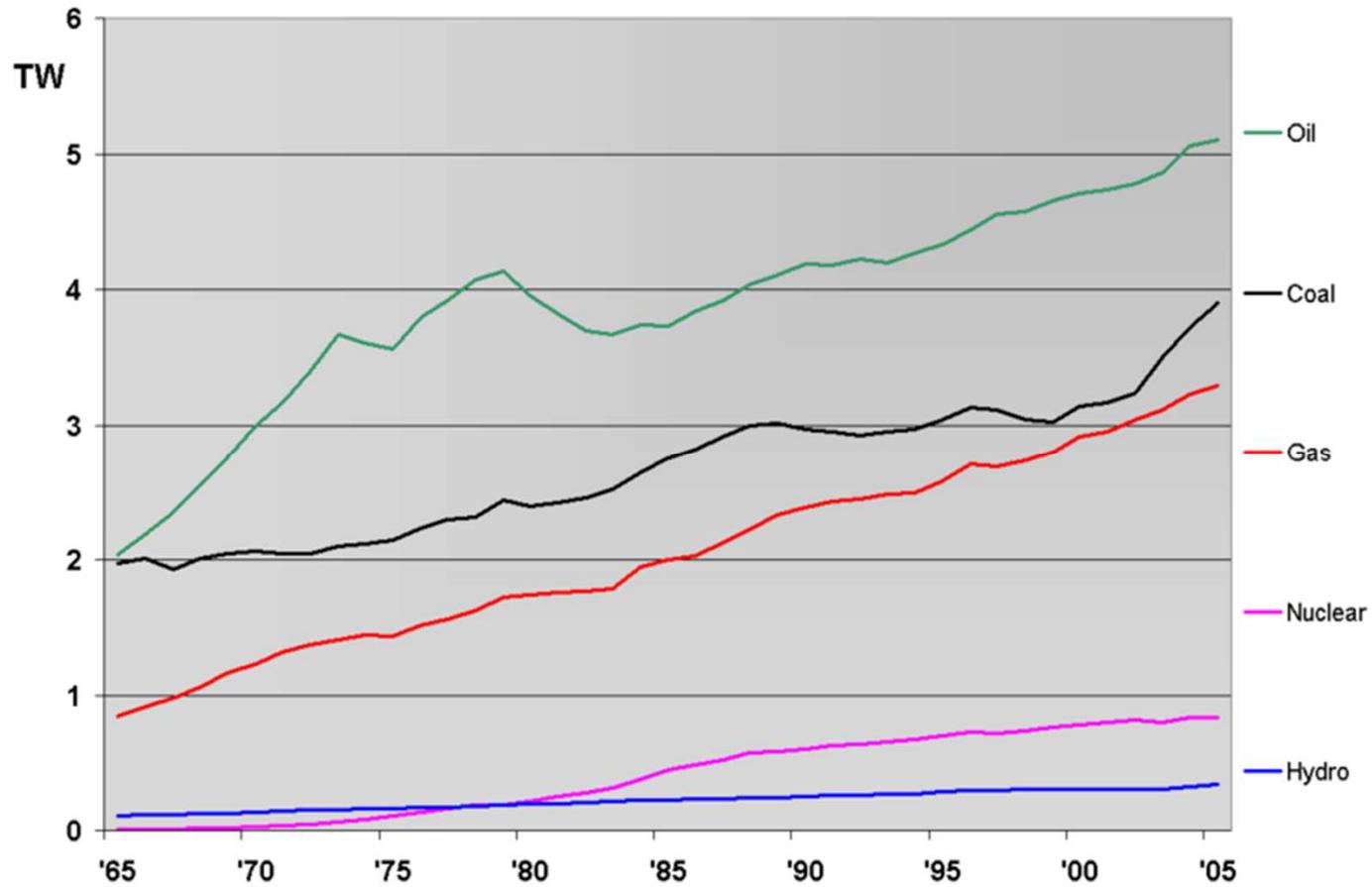


- Hydrogen and fuel cells are technology solutions that are part of an integrated and sustainable energy system for future generations
- Continued innovation in this sector advances national objectives of:
  - Economic development and job creation
  - Enhancing Canada’s science and technology capacity
  - Clean air (eliminates  $\text{NO}_x$ ,  $\text{SO}_x$ , CO and particulates)
  - Greenhouse gas emission reduction
  - Reducing the carbon impact of Canada’s oil and gas resources

# The Need For Energy



# World Annual Energy Consumption in Terrawatts



## How Can the Demand Be Met?

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



# 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

Stored energy  
or energy of  
position

Gravitational, Stored  
Mechanical, Nuclear,  
Chemical

## KINETIC

Energy of  
motion

Motion, Electrical,  
Sound, Radiant,  
Thermal

## Potential Energy

### Gravitational Energy

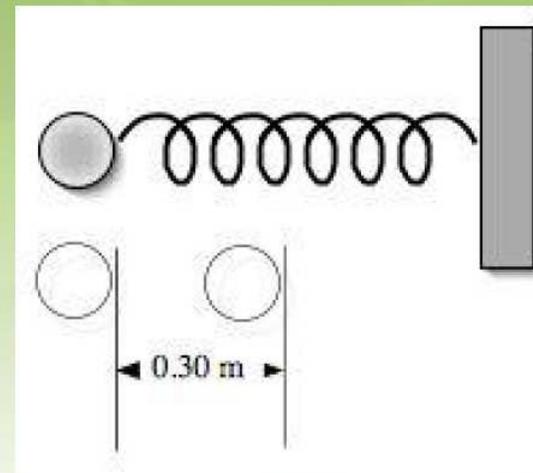
– energy an object or substance has because of its position

Anything “up high”



## Potential Energy

**Stored Mechanical Energy** – stored in an object by the application of force  
Must push or pull on an object



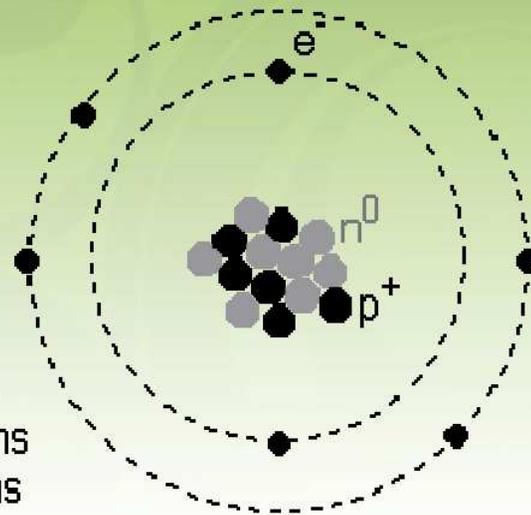
## Potential Energy

### Nuclear Energy –

energy stored in the nucleus of an atom

Holds the atom together

$^{14}_6\text{Carbon}$



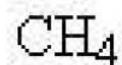
6 protons  
6 electrons  
8 neutrons

## Potential Energy

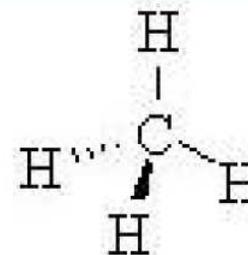
### Chemical Energy –

energy stored in the bonds between atoms

Holds molecules together



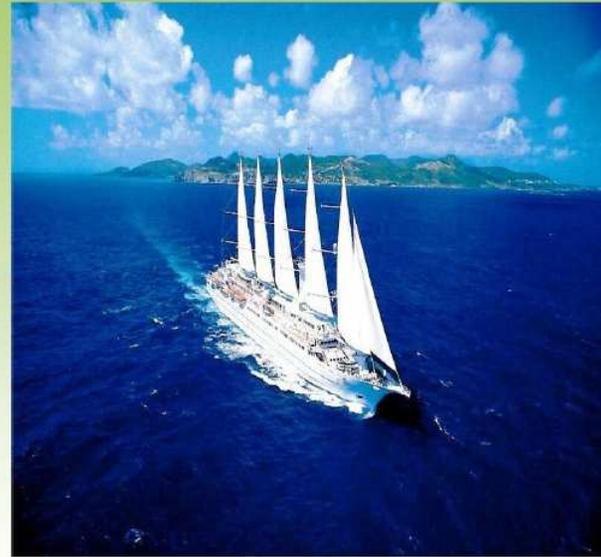
Molecular  
Formula



Perspective  
Drawing

## Kinetic Energy

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

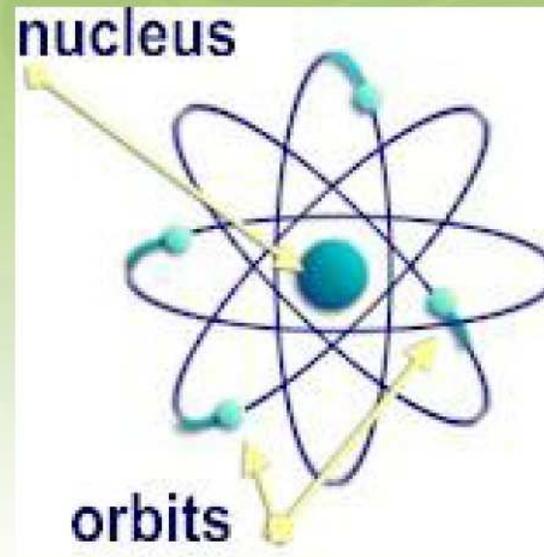


## Kinetic Energy

### Electrical Energy

– movement of electrons

NOT AN ELECTRON PARADE!



## Kinetic Energy

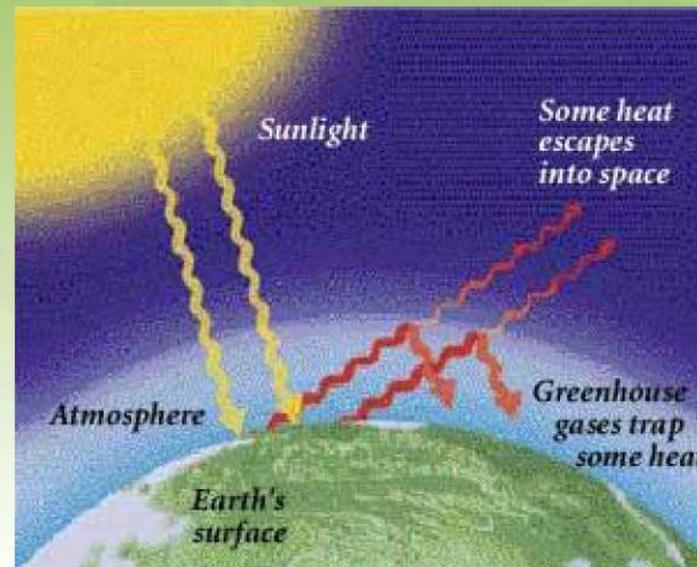
### Sound Energy

– 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

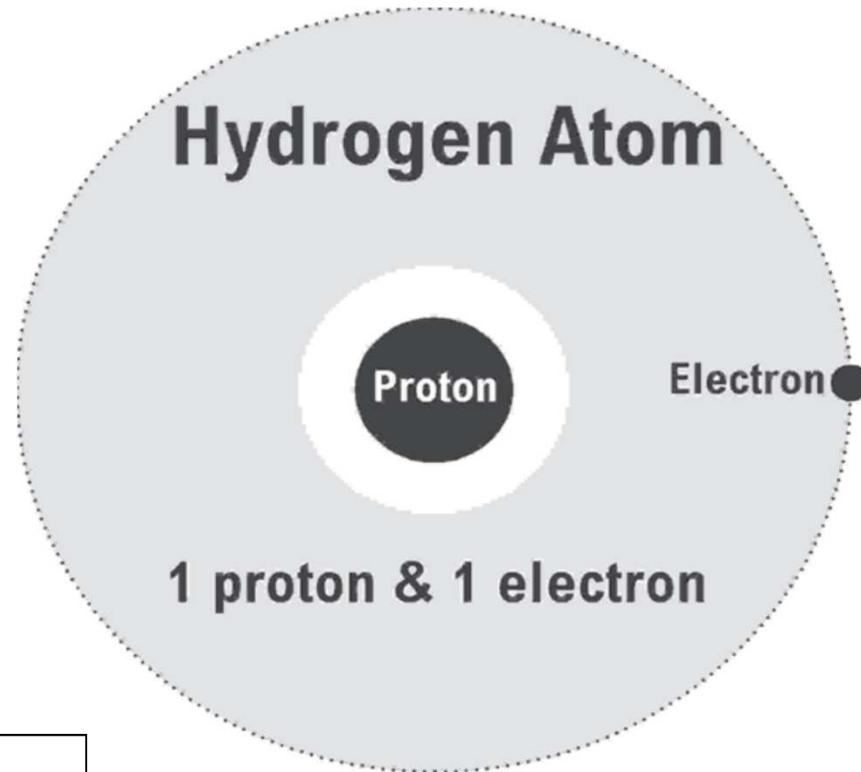
- Hydrogen is the universe's most common and simplest element.
  - As a fuel it provides benefits to energy security, the environment and economic growth.
  - Consisting of one proton and one electron, on earth it is found bonded to other elements (for example, when combined with oxygen, it forms water - H<sub>2</sub>O).
- 
- 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

## PERIODIC TABLE OF THE ELEMENTS

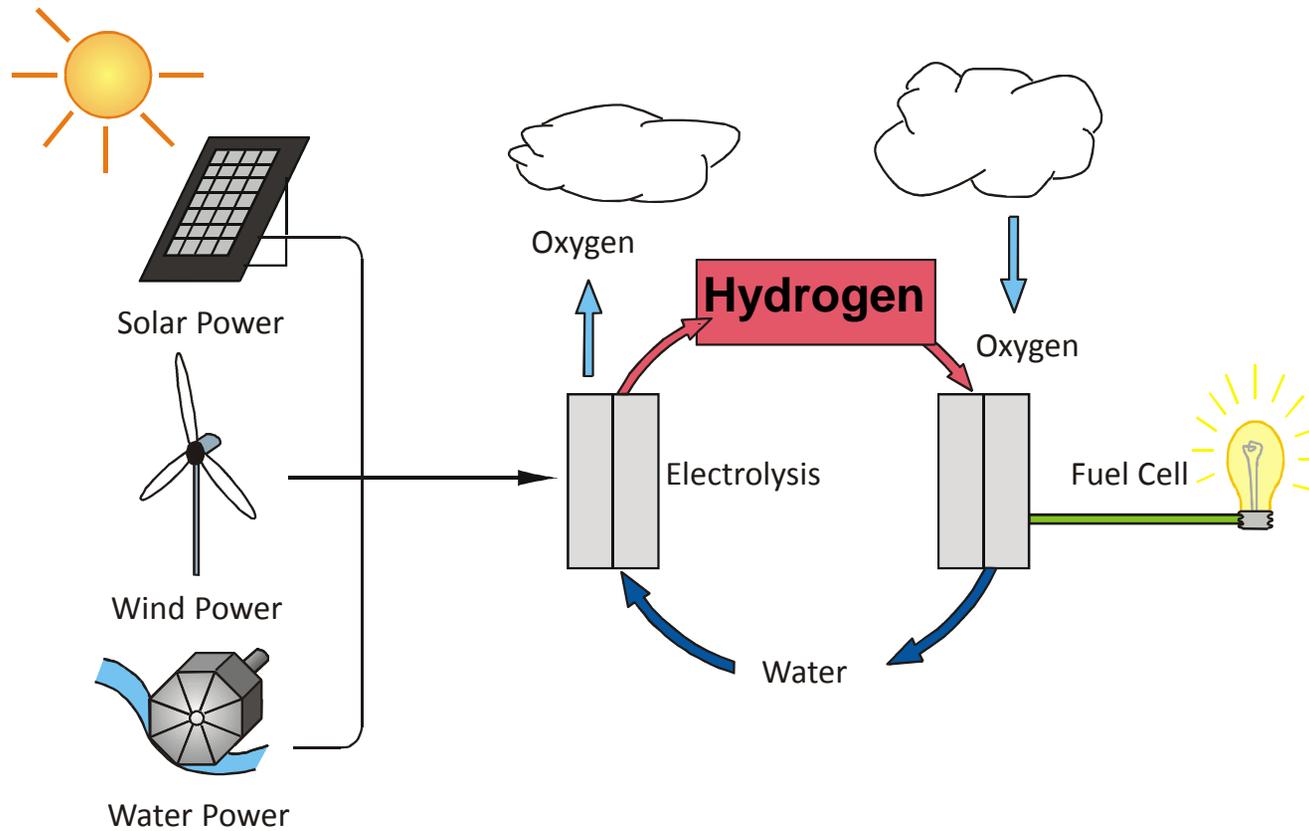
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 <b>H</b> Hydrogen 1.008																	2 <b>He</b> Helium 4.003
3 <b>Li</b> Lithium 6.941	4 <b>Be</b> Beryllium 9.012											5 <b>B</b> Boron 10.81	6 <b>C</b> Carbon 12.01	7 <b>N</b> Nitrogen 14.01	8 <b>O</b> Oxygen 16.00	9 <b>F</b> Fluorine 19.00	10 <b>Ne</b> Neon 20.18
11 <b>Na</b> Sodium 22.99	12 <b>Mg</b> Magnesium 24.31											13 <b>Al</b> Aluminum 26.98	14 <b>Si</b> Silicon 28.09	15 <b>P</b> Phosphorus 30.97	16 <b>S</b> Sulfur 32.07	17 <b>Cl</b> Chlorine 35.45	18 <b>Ar</b> Argon 39.95
19 <b>K</b> Potassium 39.10	20 <b>Ca</b> Calcium 40.08	21 <b>Sc</b> Scandium 44.96	22 <b>Ti</b> Titanium 47.88	23 <b>V</b> Vanadium 50.94	24 <b>Cr</b> Chromium 52.00	25 <b>Mn</b> Manganese 54.94	26 <b>Fe</b> Iron 55.85	27 <b>Co</b> Cobalt 58.93	28 <b>Ni</b> Nickel 58.69	29 <b>Cu</b> Copper 63.55	30 <b>Zn</b> Zinc 65.39	31 <b>Ga</b> Gallium 69.72	32 <b>Ge</b> Germanium 72.59	33 <b>As</b> Arsenic 74.92	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.90	36 <b>Kr</b> Krypton 83.80
37 <b>Rb</b> Rubidium 85.47	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.91	40 <b>Zr</b> Zirconium 91.22	41 <b>Nb</b> Niobium 92.91	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.1	45 <b>Rh</b> Rhodium 102.9	46 <b>Pd</b> Palladium 106.4	47 <b>Ag</b> Silver 107.9	48 <b>Cd</b> Cadmium 112.4	49 <b>In</b> Indium 114.8	50 <b>Sn</b> Tin 118.7	51 <b>Sb</b> Antimony 121.8	52 <b>Te</b> Tellurium 127.6	53 <b>I</b> Iodine 126.9	54 <b>Xe</b> Xenon 131.3
55 <b>Cs</b> Cesium 132.9	56 <b>Ba</b> Barium 137.3	*	72 <b>Hf</b> Hafnium 178.5	73 <b>Ta</b> Tantalum 180.9	74 <b>W</b> Tungsten 183.9	75 <b>Re</b> Rhenium 186.2	76 <b>Os</b> Osmium 190.2	77 <b>Ir</b> Iridium 190.2	78 <b>Pt</b> Platinum 195.1	79 <b>Au</b> Gold 197.0	80 <b>Hg</b> Mercury 200.5	81 <b>Tl</b> Thallium 204.4	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 209.0	84 <b>Po</b> Polonium (210)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	**															
		* Lanthanide Series	57 <b>La</b> Lanthanum 138.9	58 <b>Ce</b> Cerium 140.1	59 <b>Pr</b> Praseodymium 140.9	60 <b>Nd</b> Neodymium 144.2	61 <b>Pm</b> Promethium (147)	62 <b>Sm</b> Samarium 150.4	63 <b>Eu</b> Europium 152.0	64 <b>Gd</b> Gadolinium 157.3	65 <b>Tb</b> Terbium 158.9	66 <b>Dy</b> Dysprosium 162.5	67 <b>Ho</b> Holmium 164.9	68 <b>Er</b> Erbium 167.3	69 <b>Tm</b> Thulium 168.9	70 <b>Yb</b> Ytterbium 173.0	71 <b>Lu</b> Lutetium 175.0
		** Actinide Series	89 <b>Ac</b> Actinium (227)	90 <b>Th</b> Thorium 232.0	91 <b>Pa</b> Protactinium (231)	92 <b>U</b> Uranium (238)	93 <b>Np</b> Neptunium (237)	94 <b>Pu</b> Plutonium (242)	95 <b>Am</b> Americium (243)	96 <b>Cm</b> Curium (247)	97 <b>Bk</b> Berkelium (247)	98 <b>Cf</b> Californium (249)	99 <b>Es</b> Einsteinium (254)	100 <b>Fm</b> Fermium (253)	101 <b>Md</b> Mendelevium (256)	102 <b>No</b> Nobelium (254)	103 <b>Lr</b> Lawrencium (257)

# Hydrogen Basics



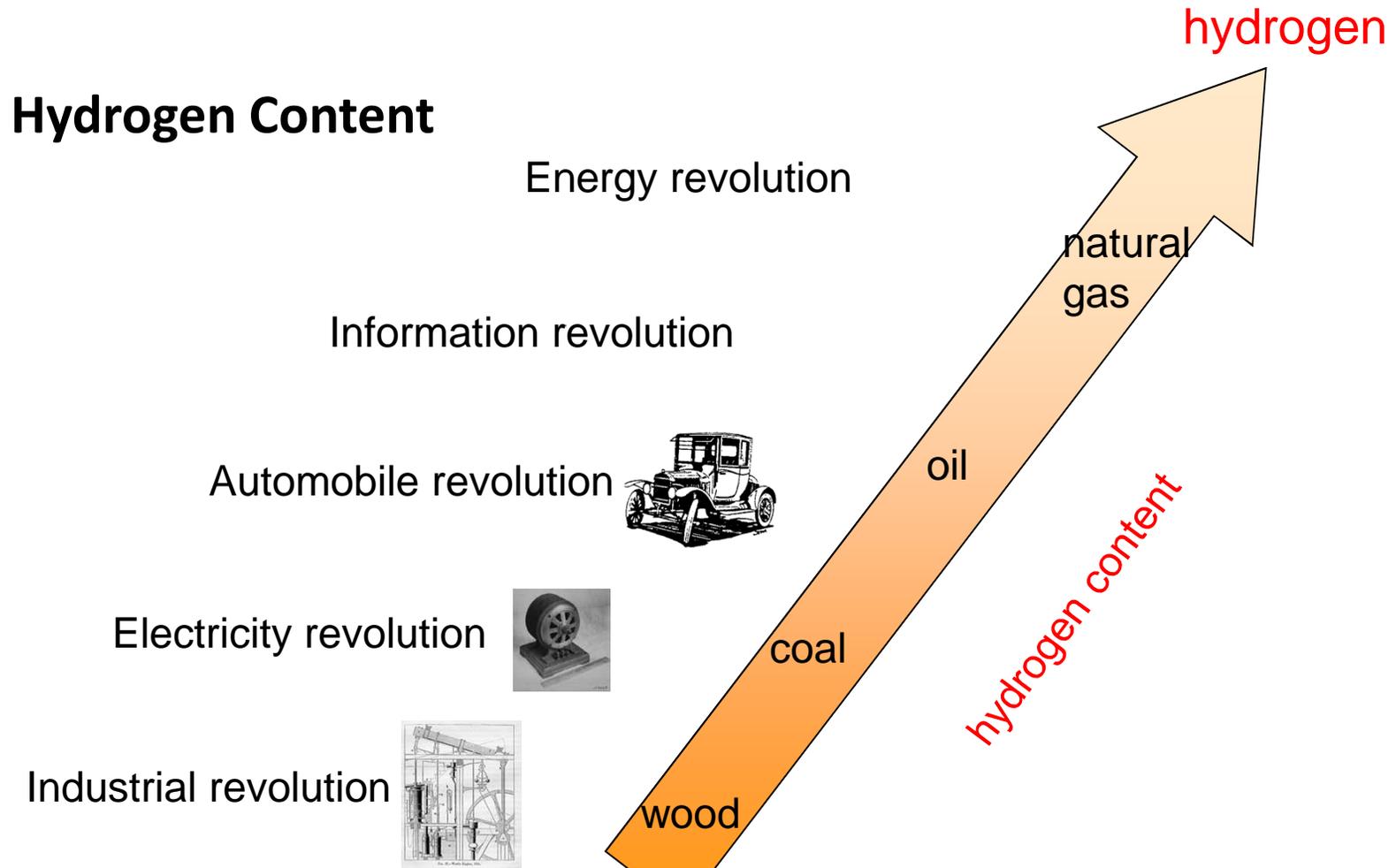
Protons have a + charge  
Electrons have a - charge

# Where does hydrogen come from?

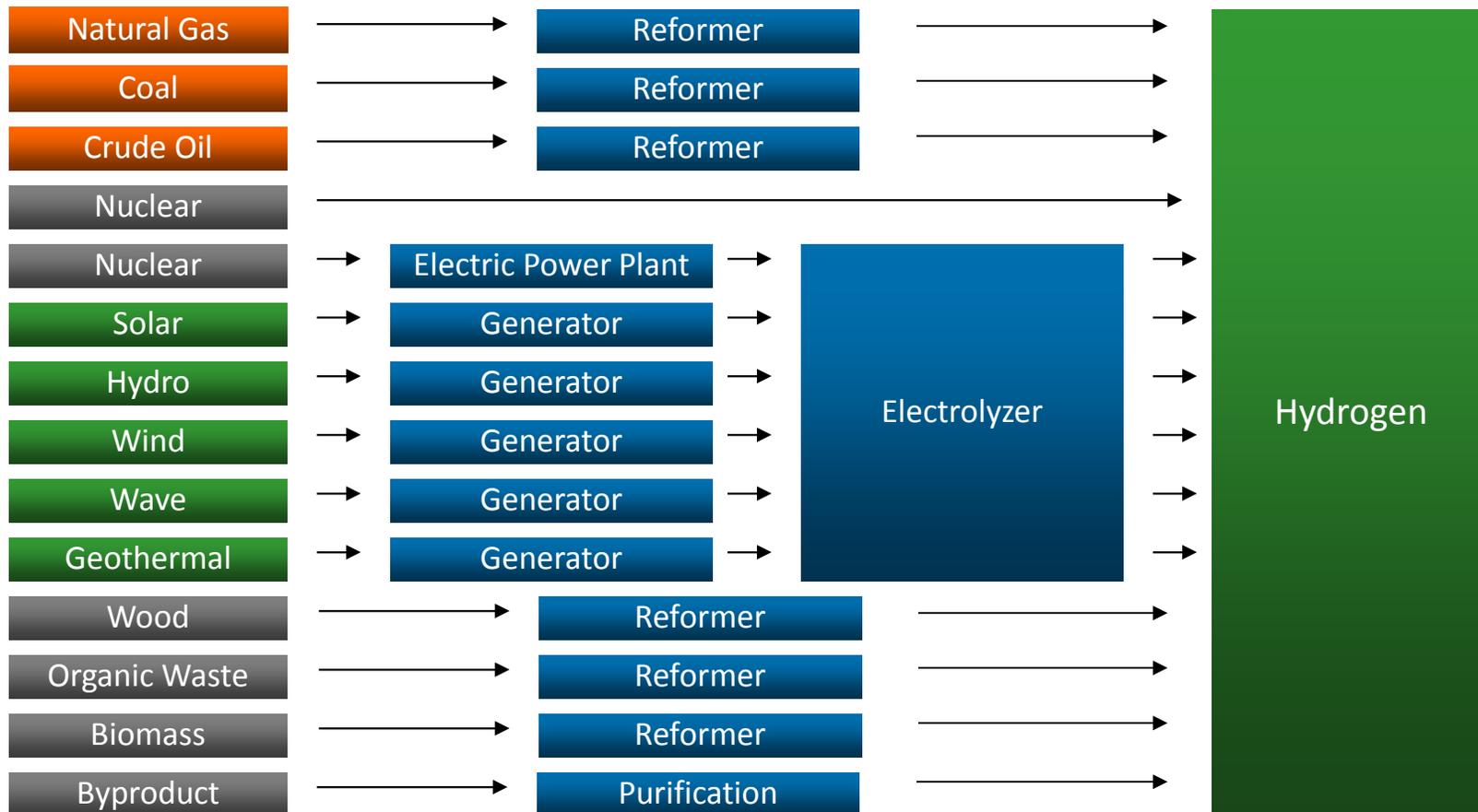


# Hydrogen Through The Years

## Hydrogen Content



# 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)

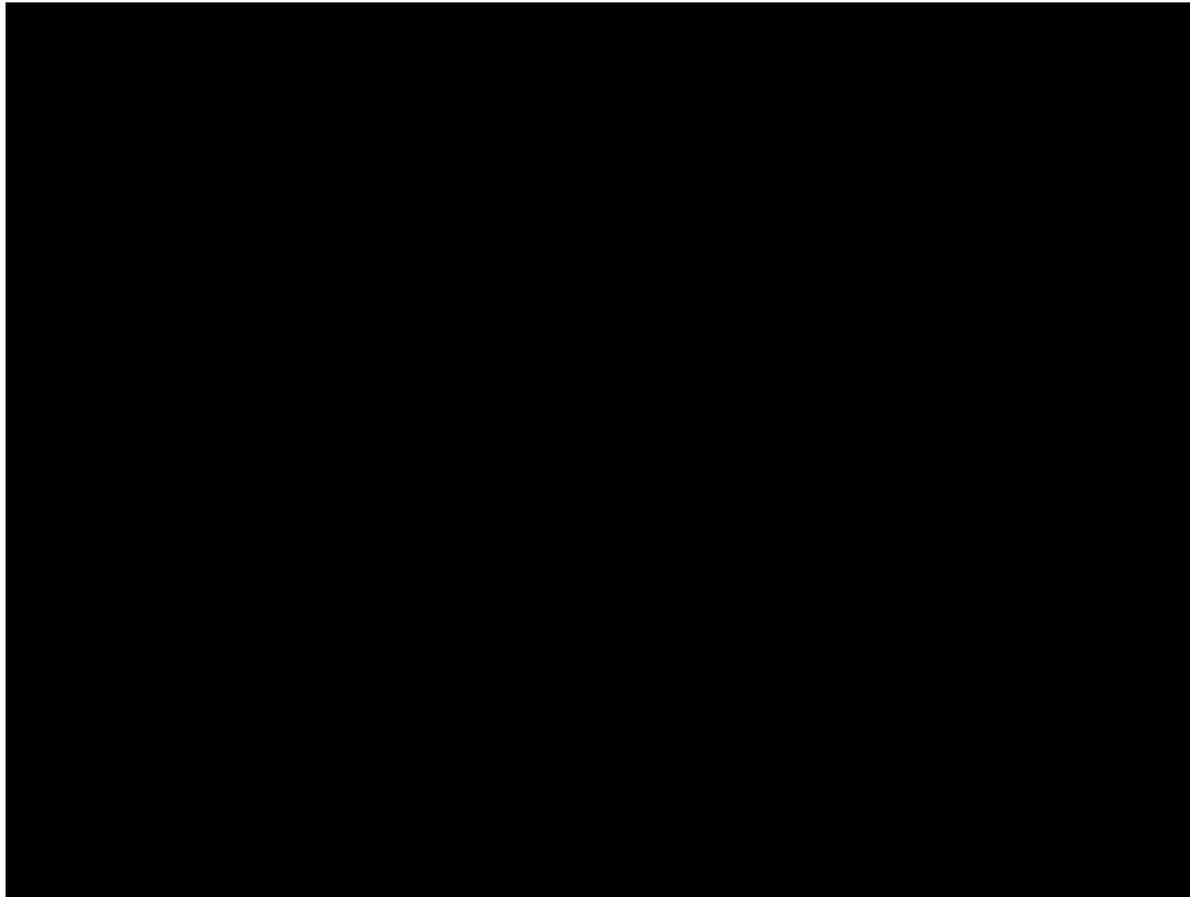
## What is a fuel cell?

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

### **Benefits:**

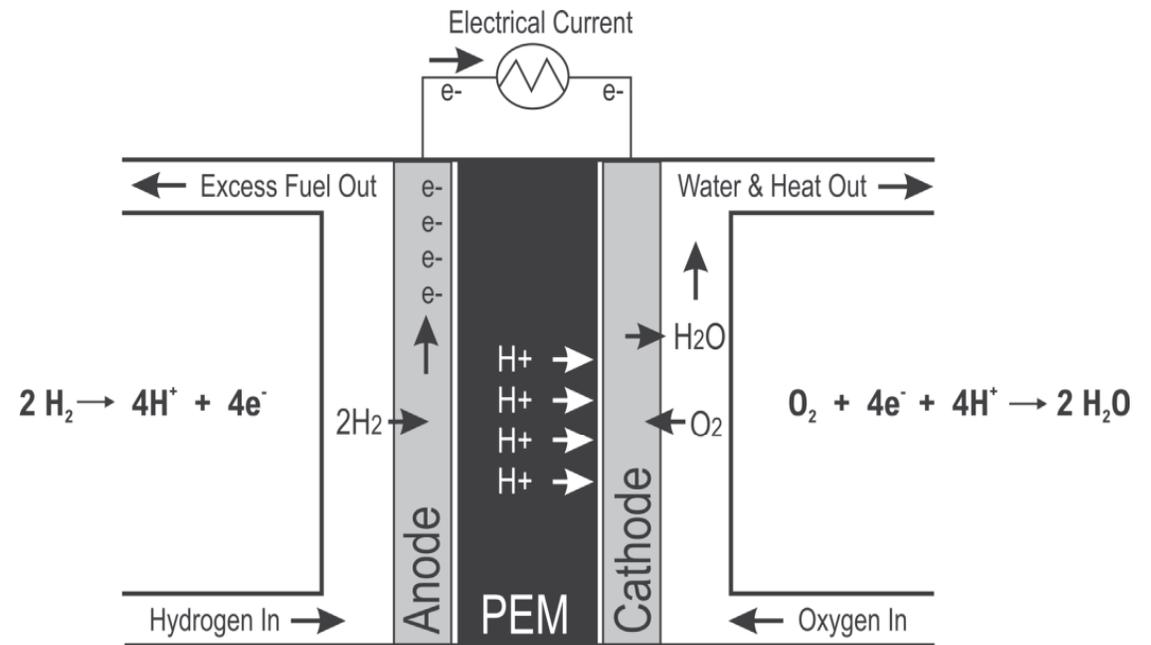
- Superior energy efficiency
- Multiple feedstocks: hydrogen, methanol, natural gas, formic acid, ethanol
- Zero to near-zero emissions
- Versatility – can be utilized in micro, portable, stationary, and mobile power applications
- Low maintenance costs, quiet operation, flexibility for innovative designs

## What is a fuel cell?



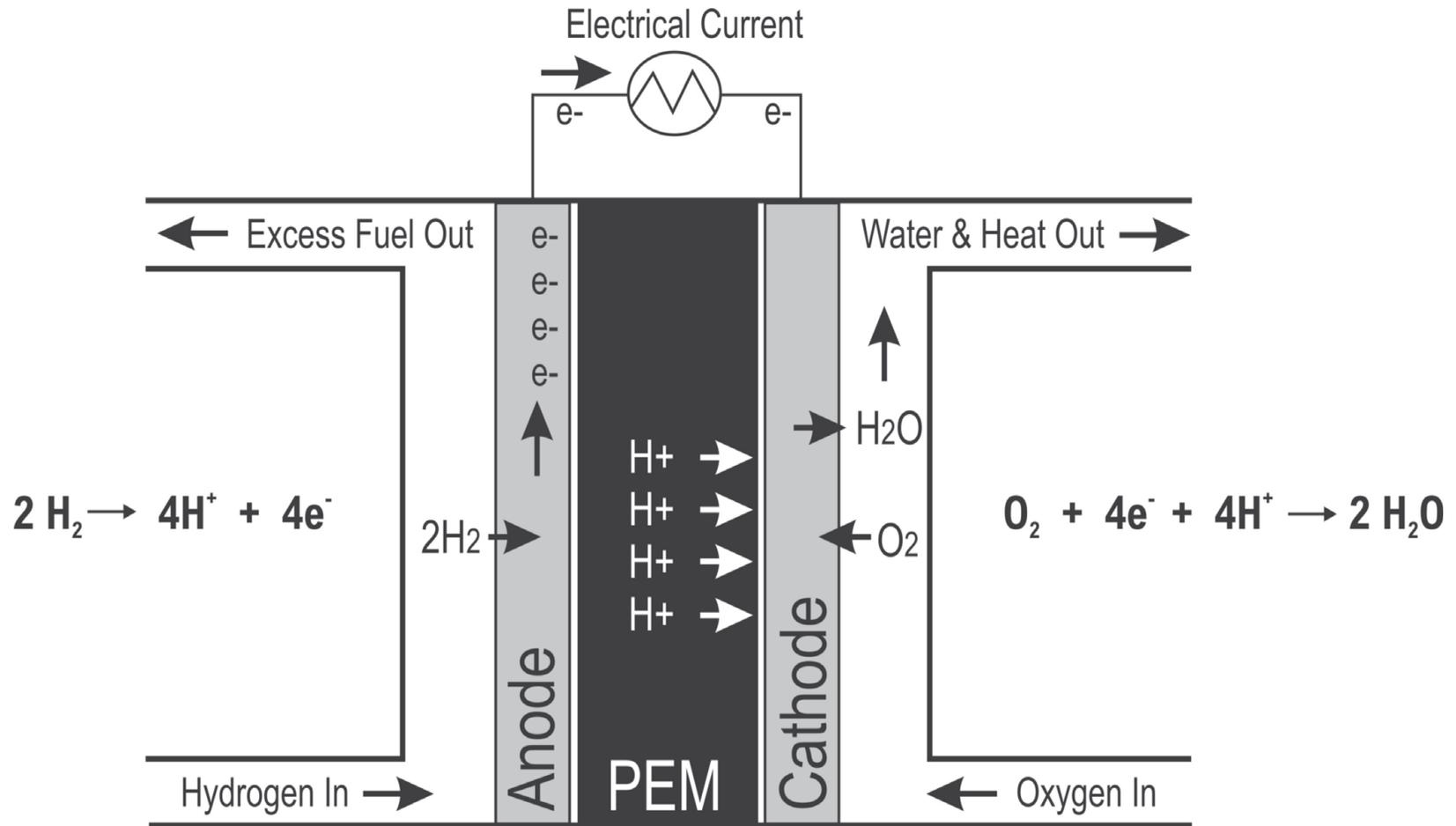
# How a Fuel Cell Works

- 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.

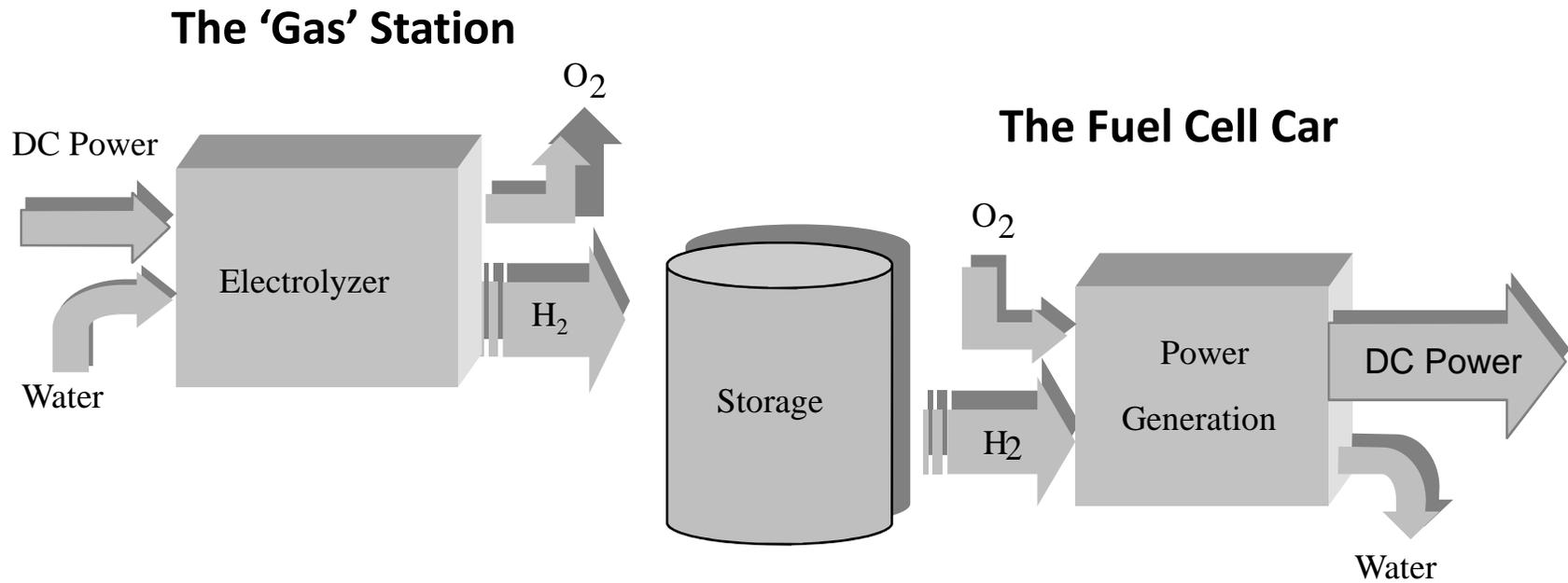
## Hands-On with a Fuel Cell Model Car

- 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

