FUEL CELLS
One of the essential problems of clean energy is that it is often unreliable.

We need an effective way to store intermittent and unreliable energies for later use.

What are some ways you know of how to store energy?
The fuel cell was first posited by Sir William Grove in 1839. After observing the fact that electricity flowing into water would create hydrogen and oxygen gas, he assumed that there must be some way to get that electricity back out.

- **Hydrogen Generation Philosophy One**
- **Hydrogen Generation Philosophy Two**

\[ 2\text{H}_2\text{O} + e^- \rightleftharpoons 2\text{H}_2 + \text{O}_2 \]
Kinds of Fuel Cells

Proton exchange membrane fuel cell (PEMFC or PEM)
The Department of Energy (DOE) is focusing on the PEMFC as the most likely candidate for transportation applications. The PEMFC has a high power density and a relatively low operating temperature (ranging from 60 to 80 degrees Celsius, or 140 to 176 degrees Fahrenheit). The low operating temperature means that it doesn't take very long for the fuel cell to warm up and begin generating electricity.

Solid oxide fuel cell (SOFC)

Alkaline fuel cell (AFC)  
Molten-carbonate fuel cell (MCFC)  
Phosphoric-acid fuel cell (PAFC)  
Direct-methanol fuel cell (DMFC)

Most of these are either very expensive, difficult to build, or must operate at high temperatures

Source: How Stuff Works
Basic Functionality of PEMFC

- The **anode**, the negative post of the fuel cell, conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit.

- The **cathode**, the positive post of the fuel cell, conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

- The **proton exchange membrane** is a specially treated material, which looks something like ordinary kitchen plastic wrap, only conducts positively charged ions.

- The **catalyst** is a special material that facilitates the reaction of oxygen and hydrogen. It is usually made of platinum nanoparticles very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen. The platinum-coated side of the catalyst faces the PEM.

Source: How Stuff Works
Pros and Cons

- **Pros**
  - Simple clean “batteries”
  - Can create and store extra hydrogen for later use
  - Water is the only byproduct
  - “Fuel Cell” is an awesome word
  - Convenient infrastructure opportunities

- **Cons**
  - Very expensive
  - Not very powerful for their weight
  - Dangerous
  - Where does the energy for electrolysis come from?
Time to Make our Own

The Five Commandments of Fuel Cell Cars

- Thou shalt not glueth, coloreth, or otherwise disfigurith thy fuel cell
- Thou shalt not, although the opportunity may seem spectacularly tempingeth, plugeth thy motor directly into thy battery pack
- Thou shalt not saweth, glueth, or smasheth thy table
- Thou shalt not spilleth water all over thy computer
- Thou shalt have fun, learn, and buildeth a really awesome fuel cell drawn carriage
Clean Energy Fueling Station

- Charging battery configuration

Diagram 1

Wind Turbine

Solar Photovoltaic

Diode

Battery

Connector

Connector
Clean Energy Fueling Station

- Charging fuel cell configuration

Diagram 2
Clean Energy Fueling Station

- Powering Motor Configuration

Diagram 3