The Environmental Company, Inc.

ENERGY TRANSFORMATION

THE ROLE OF THE HYDROGEN FUEL CELL IN PROVIDING CLEAN ENERGY OF THE FUTURE

The Environmental Company, Inc.

ENVIRONMENTAL SUSTAINABILITY

- 1983 Brundtland Commission- Our Common Future 1987
- Sustainable Development – Development that meets the needs of the present without compromising the ability of future generations to meet their own needs
- Our Common Future depends on sustainable development

The Environmental Company, Inc.

NON-SUSTAINABLE ENERGY

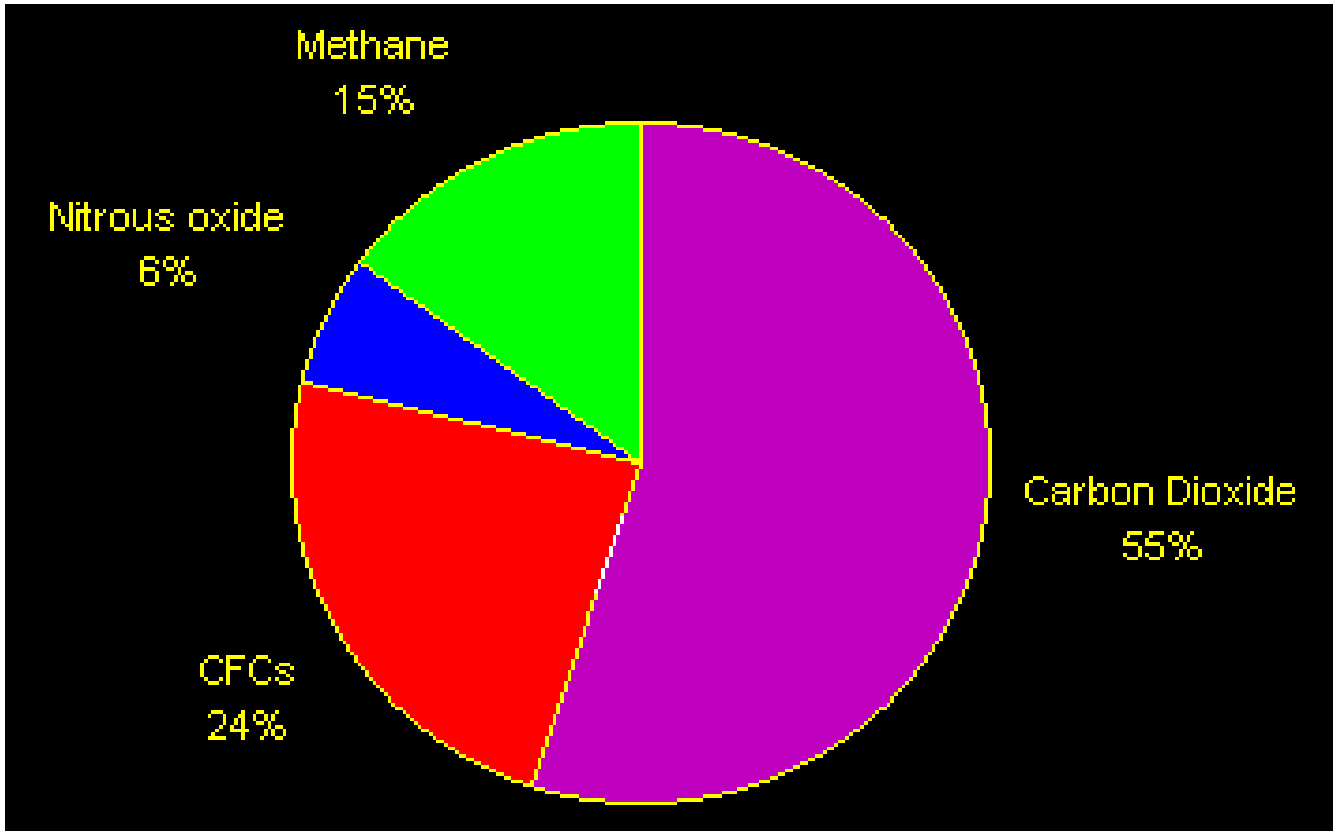
- Historically the production of energy throughout the world has not been sustainable
- Large quantities of Carbon were sequestered millions of years ago through photosynthesis in green plants
- Decay in the absence of oxygen and under temperature and pressure formed coal, oil, and natural gas
- Burning of these Hydrocarbon fuels results in the sudden release of carbon in the form of CO_2

SO WHY MUST ENERGY BE TRANSFORMED ?

- Global Warming
- Significant Challenge of 21st Century
- Effects of CO_2 Emissions
- Contribution of Fossil Fuel Energy Sources
- Alternative Energy Sources

The Environmental Company, Inc.

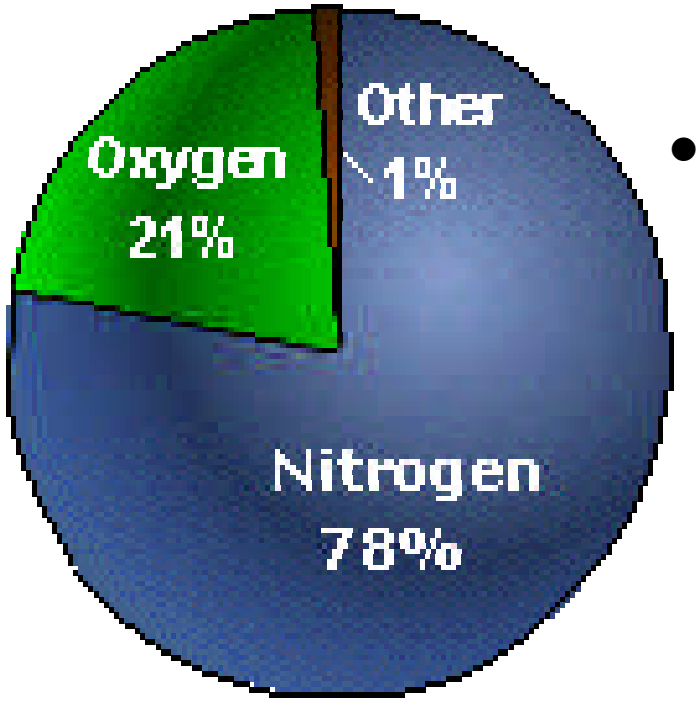
CONTRIBUTIONS TO THE GREENHOUSE EFFECT



CO_2 - a byproduct of the combustion of hydrocarbon fuels such as coal, oil, and natural gas

The Environmental Company, Inc.

Makeup of th atmosph



- The earth's atmosphere contains, by volume, 78% nitrogen, 21% oxygen, and 0.9% argon, and 0.039% other trace gases.
- Nitrogen, oxygen, and argon have no warming properties.
- Of the atmosphere's main natural constituents, only H_2O, CO_2 and O_3 have warming properties. Each of these three warming gases has 3 atoms. Their triad configuration can vibrate at the right rate to absorb and re-radiate infrared rays.

Concentration of substances in th

Cogeneration electric power generation site. Near Midland,USA
©Greenpeace/USA

- CO_2 makes up just 1/2,800th of the atmosphere. Together with other trace gases, even that tiny amount makes the earth's surface about 59^{o} warmer.

- Even a relatively small additional amount can raise the temperature of the earth significantly.

INDICATORS ???—Vs. Proof

- Rising Sea Level
- Precipitation and other climatological changes
- Altered forests, crop yields and water supplies
- Receding glaciers
- Softening of permafrost
- Coral bleaching

Portage Glacier near Anchorage, Alaska

Portage Glacier 1950

Portage Glacier 2001

The Environmental Company, Inc.

Warming Winds, Rising Tides: Oceans

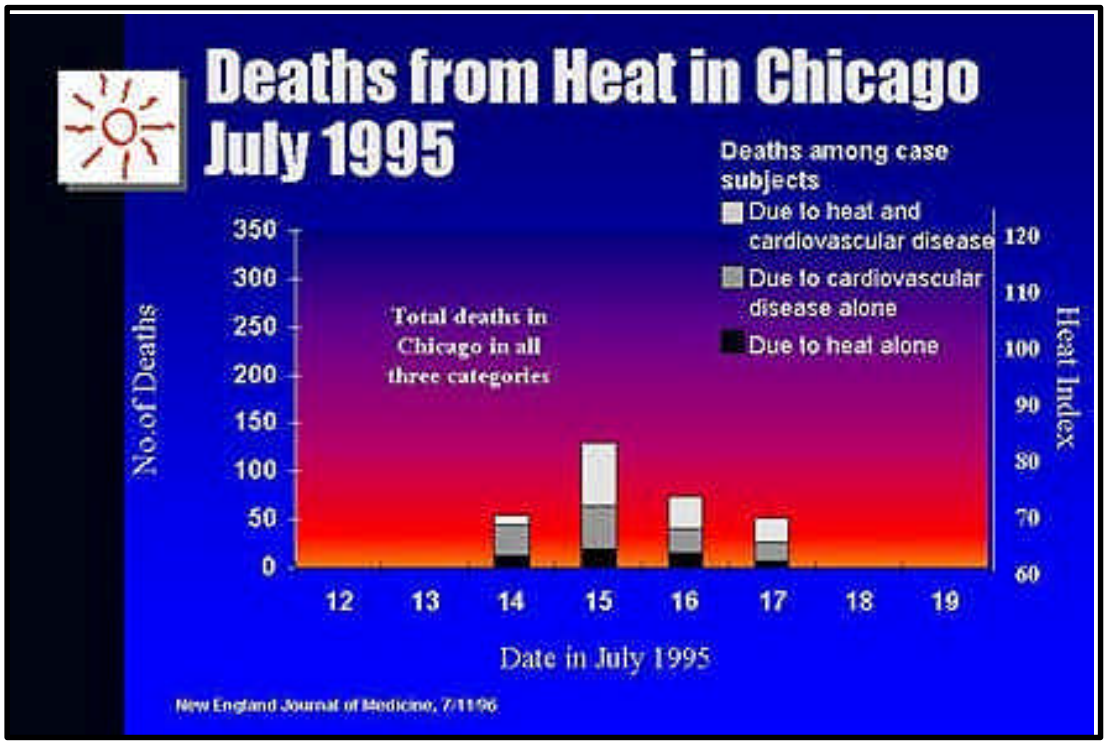
- Rising temperatures in ocean waters are a contributing cause
- Whitening of coral colonies due to the loss of symbiotic zooanthallae from the tissue of Polyps
- This loss exposes the white calcium carbonate skeletons of the coral colony

The Disintegrating Face of the Muller Ice Shelf

- Antarctic continent is surrounded by floating ice sheets called ice shelves.
- They fringe almost half the coastline.
- This is the Muller ice shelf on the Antarctic peninsula.
- It exhibits a phenomenon similar to the Portage Glacier in Alaska.

The Environmental Company, Inc.

Human Health Effects



Death rates increase on extremely hot days—July 1995 heat wave in Chicago killed more than 700 people.

The Environmental Company, Inc.

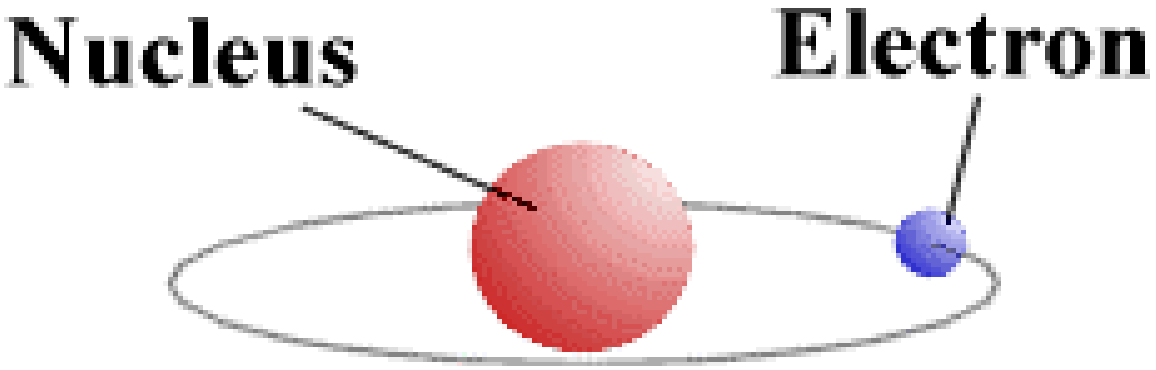
So–if CO_2 Emissions from Fossil Fuels are so bad–

What's the Alternative

The Environmental Company, Inc.

HYDROGEN

- **SIMPLEST ATOM**
- **MOST PLENTIFUL ELEMENT IN THE UNIVERSE**
- **DOES NOT OCCUR NATURALLY AS A GAS**
- **ALWAYS COMBINED WITH OTHER ELEMENTS**
- **OFTEN WITH OXYGEN AS WATER OR IN ORGANIC COMPOUNDS**



The Environmental Company, Inc.

SOURCES OF H_2

- Reforming- The process of freeing H_2 from hydrocarbons by applying heat to:
  - Natural gas, methanol, propane, gasoline
  - Currently most H_2 is made this way from natural gas
  - Problem…reforming H_2 costs more than combusting hydrocarbon fuels in their natural state
- Certain algae and bacteria, using sunlight as their energy source, give off H_2

HYDROGEN FROM POND SCUM?

ABC News Feb 2001

Pond Scum as

Fuel Factories

Starved of Oxygen, Plants Produce Hydrogen

Sun + Algae + Water = Hydrogen

Green algae, a simple plant that grows all over the world, has the unique ability to convert water and sunlight into hydrogen gas.

LIVING IN TWO RADICALLY DIFFERENT ENVIRONMENTS

- In ordinary air and sunlight algae uses photosynthesis like other plants to produce oxygen.

- But when deprived of a key nutrient, sulfur, and forced to live in an oxygen free environment, it takes up a different lifestyle.

The Environmental Company, Inc.

DUAL METABOLISM

- Under these conditions the algae throws a metabolic switch in order to survive.

- In an alternative way of breathing, developed over millions of years in an environment where there is no sulfur or oxygen, the algae makes hydrogen.

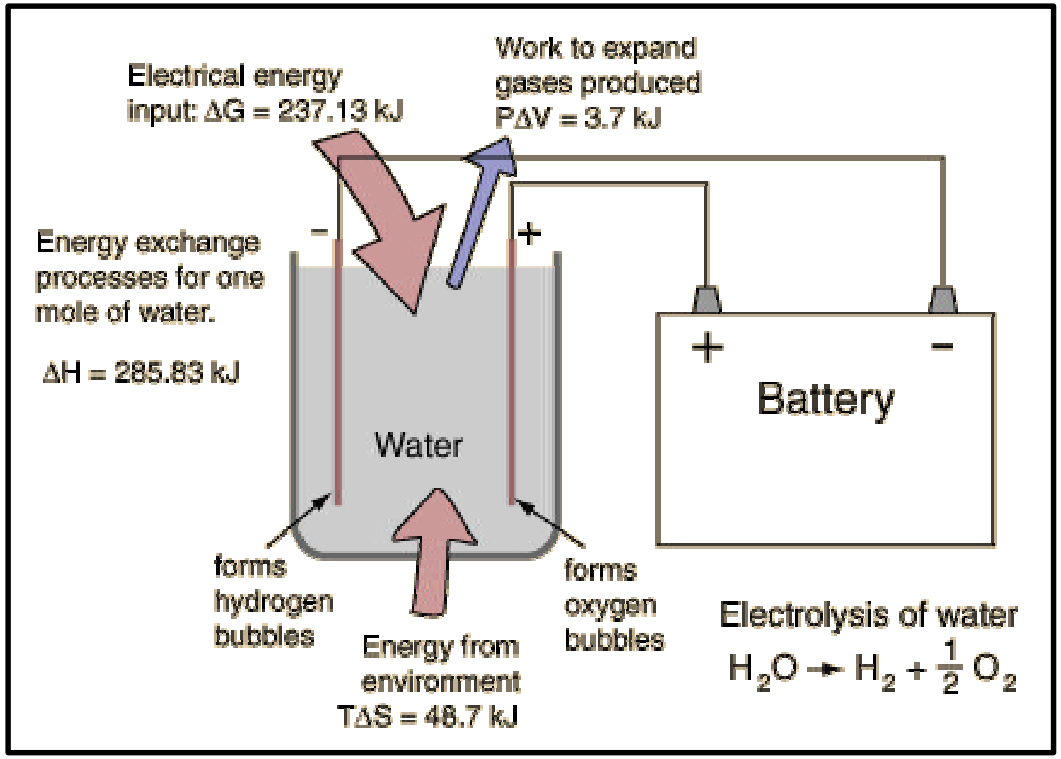
The Environmental Company, Inc.

FORCING THE SWITCH

- In experiments, algae cells are grown in the ordinary way, giving plants sunlight and nutrients.
- Then the supply of sulfur and oxygen is cut off, forcing it to click the metabolic switch.
- Within a few hours the algae begins producing pure hydrogen.

The Environmental Company, Inc.

Electrolysis of Water : The producing of chemical changes by passage of an electric current through an electrolyte.



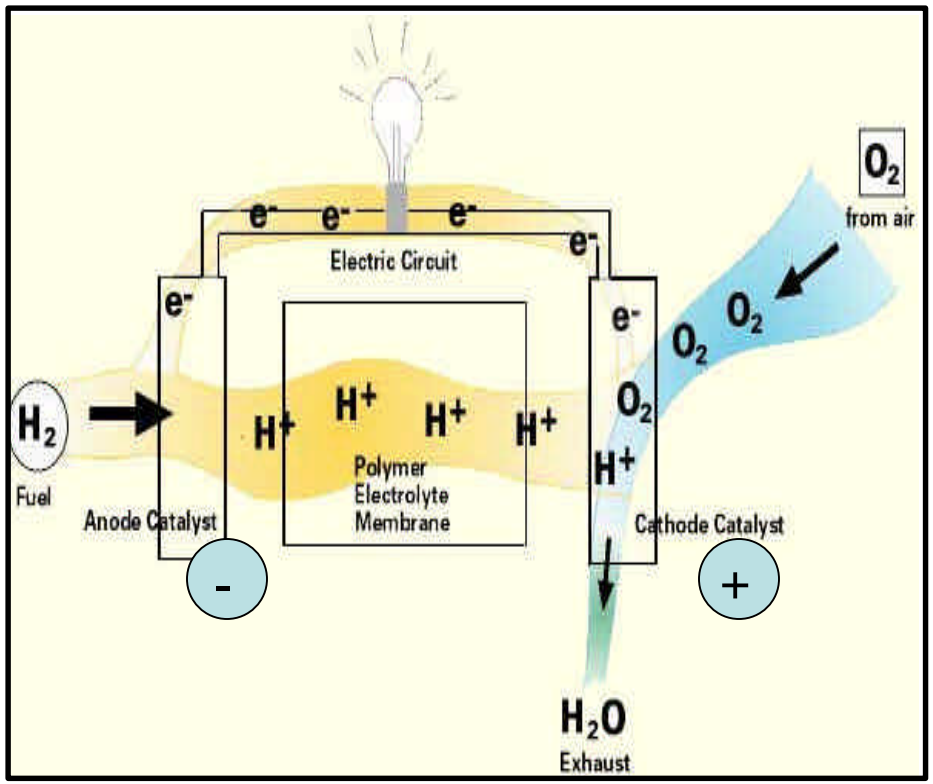
- **One of the earliest methods of producing H_2**
- **Large scale production would require electricity from the grid**

The Environmental Company, Inc.

FOR EVERY ACTION THERE IS AN EQUAL AND OPPOSITE REACTION

The Environmental Company, Inc.

SO, WHAT IF WE REVERSE THE PROCESS AND MIX H_2 AND 0_2 ?



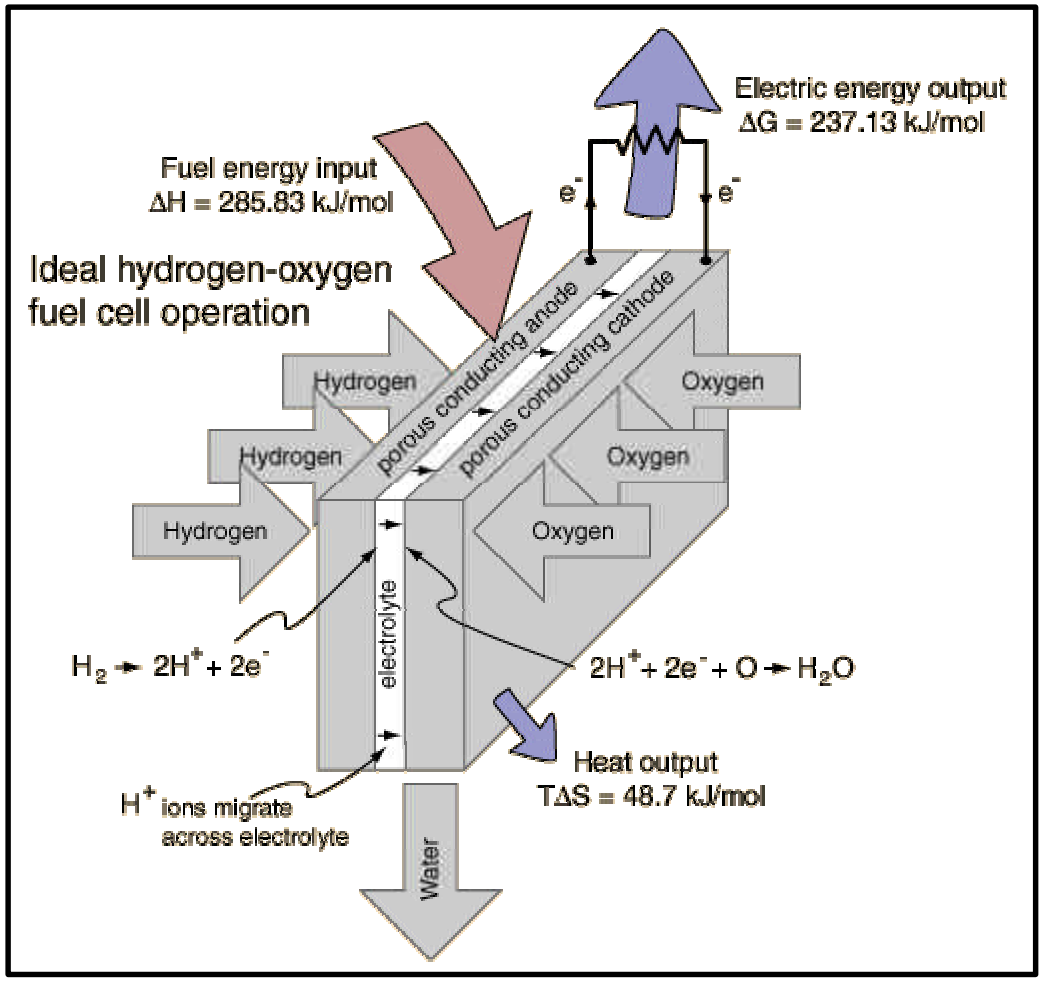
Using two electrodes sandwiched around an electrolyte:

- **oxygen passes over one electrode—**
- **hydrogen over the other—**

Generating electricity, water, and heat.

The Environmental Company, Inc.

HYDROGEN FUEL CELL



The Environmental Company, Inc.

HISTORY OF FUEL CELLS

- Discovered in 1839 By Sir William Robert Grove
- Early recognition that if electrolysis could split water into H_2 and O_2 , combining H_2 and O_2 could produce electricity
- World's first gas battery
- Fossil fuels and the steam engine prevailed
- Interest dormant until around 1960

The Environmental Company, Inc.

HIGH ENERGY AND POLLUTION FREE

NASA has used liquid H_2 to propel the space shuttle into orbit.

The Environmental Company, Inc.

DRINKING WATER FOR THE ASTRONAUTS

NASA pioneered development of fuel cells.

Hydrogen fuel cells on board the shuttle provide both electric power and pure drinking water.

The Environmental Company, Inc.

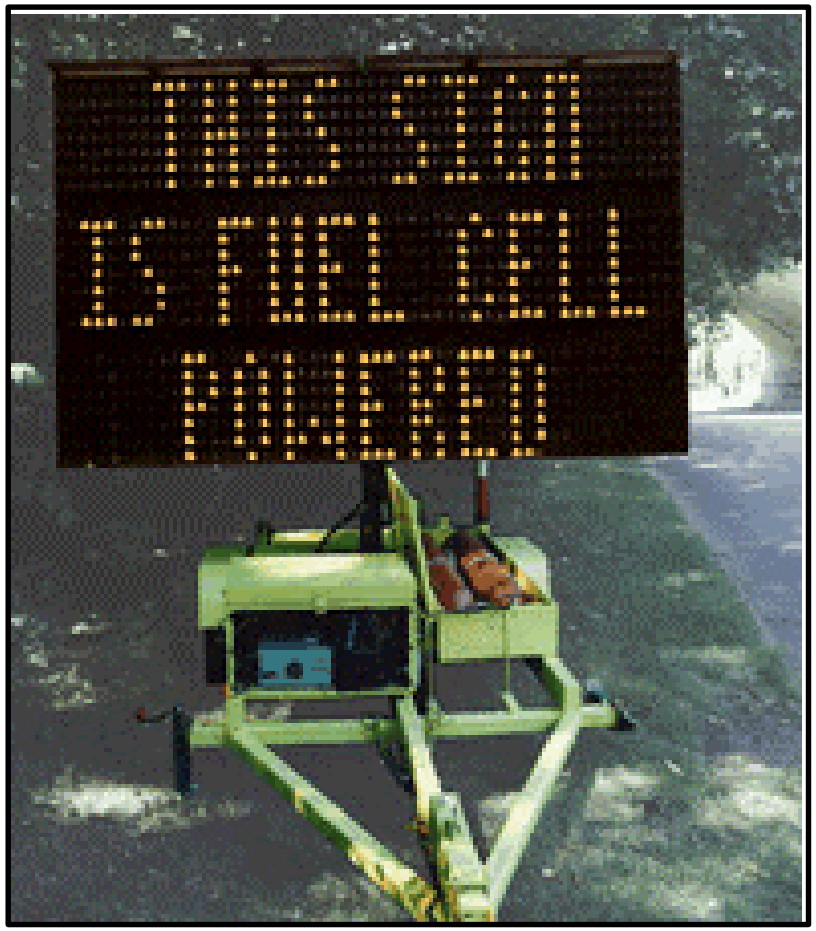
HYDROGEN FUEL CELL POWERING PORTABLE LIGHTING

The Environmental Company, Inc.

COMPUTER POWER

The Environmental Company, Inc.

ROADWAY CONSTRUCTION SIGNS

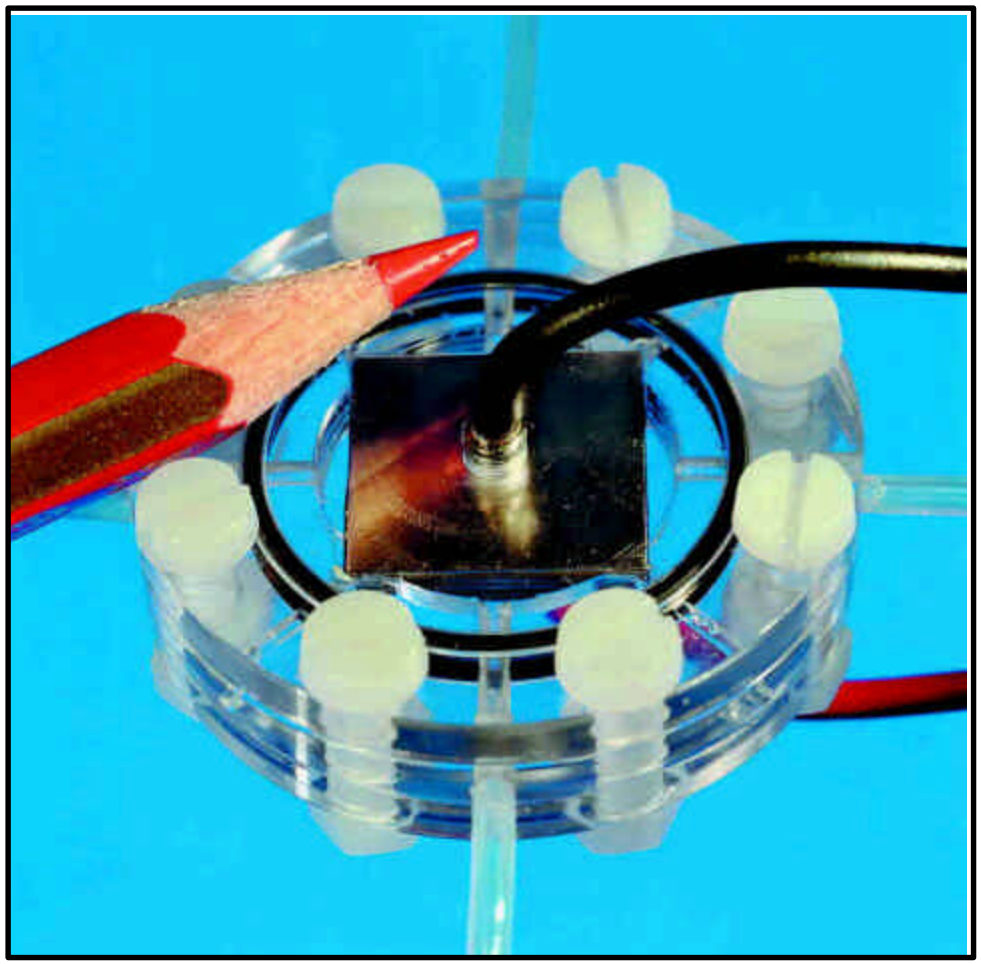


The Environmental Company, Inc.

VIDEO CAMERAS

The Environmental Company, Inc.

CELL PHONE POWER



The Environmental Company, Inc.

250 KW Proton Exchange Membrane Fuel Cell Power Plant

The only waste product is water at 170º, which could fuel the heating system for a building.

The Environmental Company, Inc.

Other Applications of Fuel Cells

Distributed Power

- **Any small-scale power generation technology that provides electric power at a site closer to customers than central station generation. (On site generation)**

- **Technologies available include turbine generators, photovoltaic panels, wind turbines, and fuel cells.**

- **These can be applicable right down to the individual residence.**

The Environmental Company, Inc.

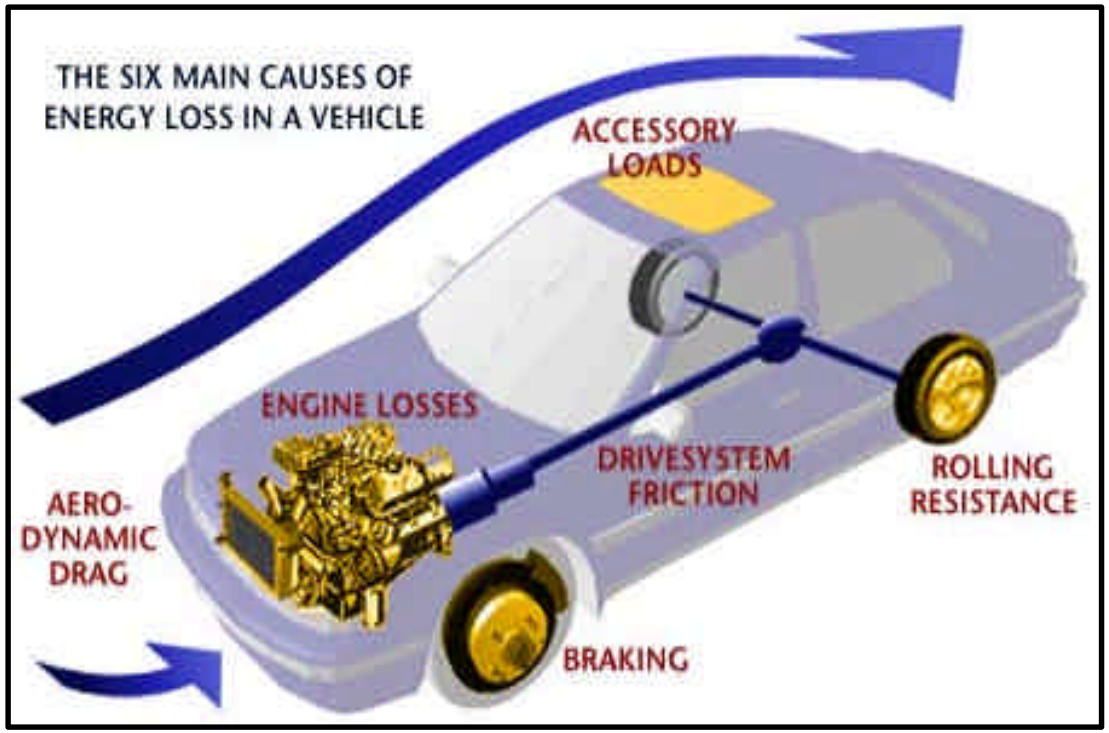
REPLACING THE INTERNAL COMBUSTION ENGINE

- Combusts 8 million barrels of non-renewable oil per day (450 gals per person annually)

- Emits 25% of U.S. Greenhouse gases

The Environmental Company, Inc.

The Six Main Causes of Energy Loss in a Vehicle

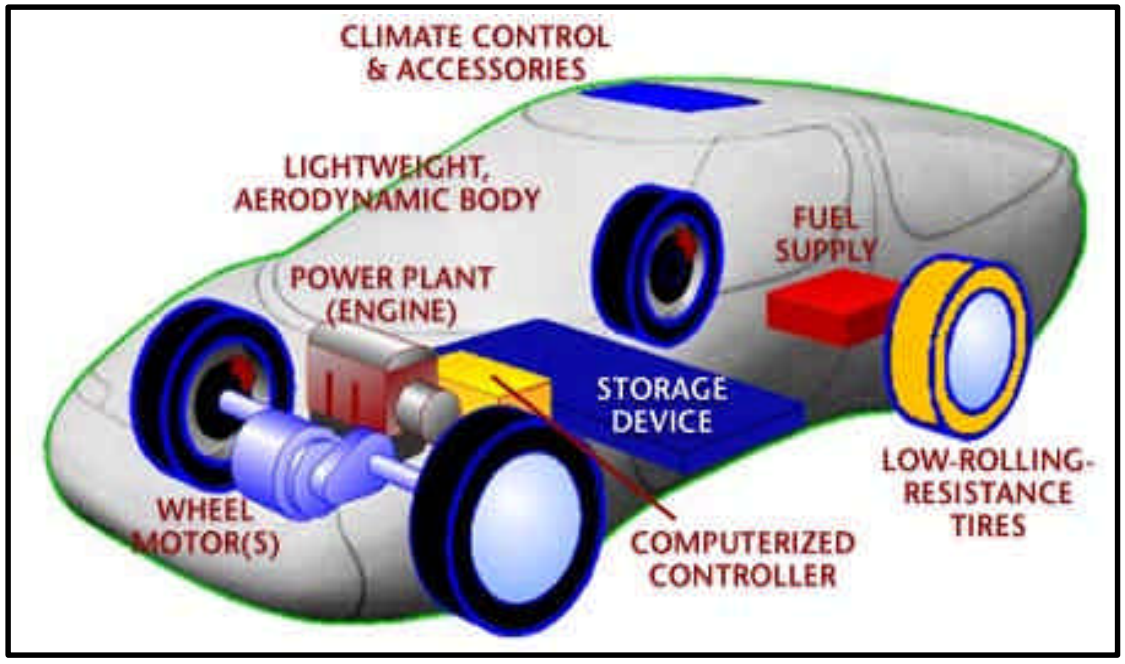


- 80% of energy in fuel lost to engine heat and exhaust
- 20% actually turns the wheels
- Of the resulting force, 95% moves the car, 5% the driver

The Environmental Company, Inc.

Th

Amory Lovins RMI



- Ultra-light construction
- Low drag design
- Hybrid-electric drive
- Efficient accessories
- Hydrogen fuel cell engine

The Environmental Company, Inc.

Daimler-Benz NECAR 4

Experimental fuel cell car

- **Liquid Hydrogen fuel**
- **Emits only water vapor**
- **Meets California standards as a zero emissions vehicle**
- **Top speed 90 MPH, cruising range 280 miles**

The Environmental Company, Inc.

With fuel cells and Hydrogen

The Environmental Company, Inc.

THE HYDROGEN ECONOMY

- The vision of building an energy infrastructure that uses hydrogen as an energy carrier.
- Many scientists and other informed individuals today believe that hydrogen will be the basic energy source that will power future societies.
- It will replace the energy sources of today - oil, coal, and natural gas.

The Environmental Company, Inc.

TOWARD A MORE SECURE AND CLEANER ENERGY FUTURE FOR AMERICA

A National Vision of America's Transition to a Hydrogen Economy—To 2030 and Beyond

The national hydrogen vision meeting Washington DC
15-16 November 2001

TRANSFORMATION HAS ALREADY BEGUN

Hydrocarbon Economy

Hydrogen Economy

Thirty years

The Environmental Company, Inc.

Questions