

# ENERGY SOURCES AND MANAGEMENT OF ELECTRICAL ENERGY

*Electrical fourth semester*



# Detailed Contents

- Renewable Energy Sources
- Hydro Energy
- Wind Energy
- Biomass Energy
- Geothermal Energy
- Radiant Solar Energy
- Chemical Batteries

# Renewable Energy Sources

- Lecture Question
  - What are the renewable energy sources? Make a list, as comprehensive as possible.
  - What are the environmental impacts of these energy sources?
- Renewable Energy Sources
  - Radiant solar energy
    - Solar heating (passive and active), solar power plants, photovoltaic cells
  - Biomass energy
    - Direct: combustion of biomass
    - Indirect: chemical conversion to biofuel
  - Wind energy
  - Hydro energy
  - Geothermal energy
    - Power plants, direct use, heat pumps
  - Ocean energy
    - Tidal; salinity-driven

# Hydro Energy

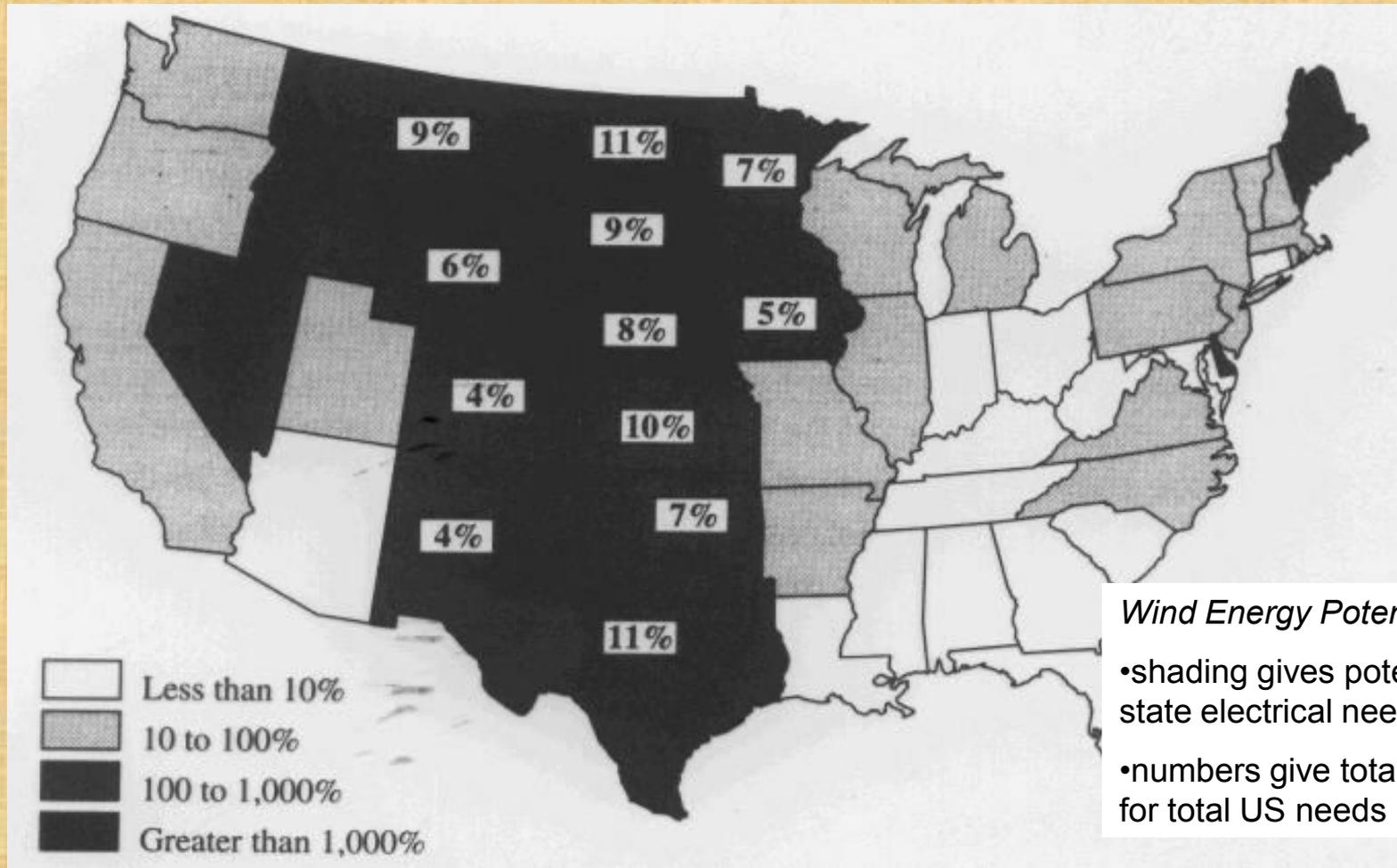
- Advantages
  - Cheap to operate
    - Long life and lower operating costs than all other power plants
  - Renewable
  - High yield
    - Lower energy cost than any other method
  - Pretty plentiful
    - Some countries depend almost entirely on it
  - Not intermittent (if reservoir is large enough)
  - Reservoirs have multiple uses
    - Flood control, drinking water, aquaculture, recreation
  - Less air pollution than fossil fuel combustion

# Hydro Energy

- Disadvantages:
  - Human population displacement
  - More significant breeding ground for disease
  - Reduces availability of water downstream
  - Ecosystem impacts
    - Barriers to migrating fish
    - Loss of biodiversity both upstream and downstream
    - Coastal erosion
    - Reduces nutrient flow (dissolved and particulate)
  - Water pollution problems
    - Low dissolved oxygen (DO)
    - Increased H<sub>2</sub>S toxicity; other DO-related problems
    - Siltation a big problem (also shortens dam life)
  - Air pollution
    - Actually may be a significant source of GHGs (CH<sub>4</sub>, N<sub>2</sub>O, CO<sub>2</sub>)
  - Decommissioning is a big problem
- The Size Issue
  - Many (most) of the above problems are significantly worse for larger dams
  - However, small dams have shorter lifetimes, less capacity, and are more intermittent

# Wind Energy

- How it works
  - Wind turbines directly generate electricity
  - Quite efficient (not a heat engine)



# Wind Energy

- Advantages
  - High net energy yield
  - Renewable and free
  - Very clean source of energy
    - No pollution (air or water) during operation
  - Long operating life
  - Low operating/maintenance costs
  - Can be quickly built; not too expensive
  - Now almost competitive with hydro and fossil fuels
  - Land can be used for other purposes
    - Can combine wind and agricultural farms

# Wind Energy

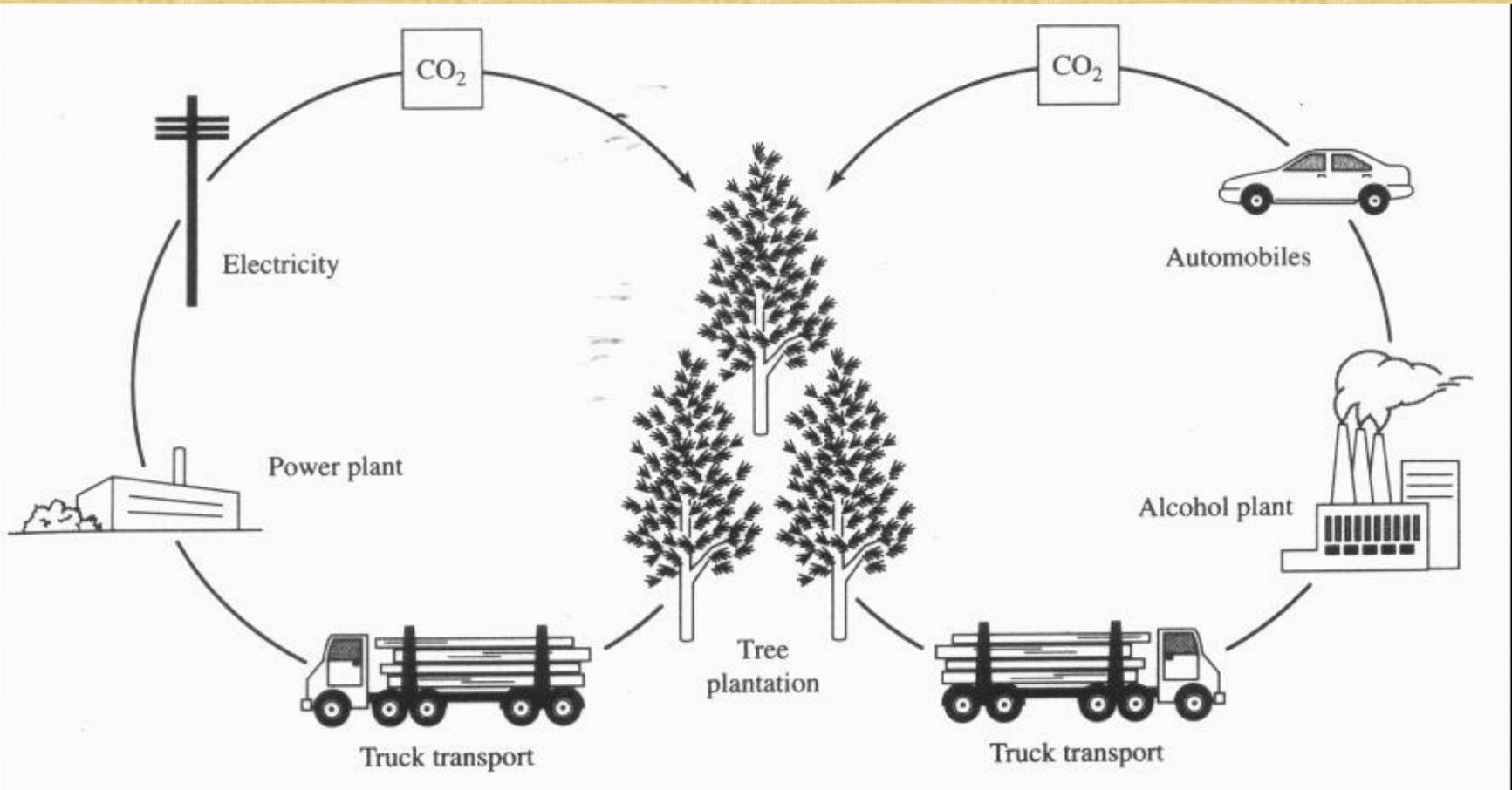
- Disadvantages
  - Energy storage issues
    - An intermittent source of energy; need backup (eg stored energy) for low-wind days
    - Or must be connected to the electrical grid
  - Only practical in areas that are windy enough
  - Visual pollution
  - Danger to birds
    - New (slow turning) designs largely eliminate this problem
  - Low energy density of wind
    - Must use large areas of land

# Biomass Energy

- What is it?
  - Biomass energy is the use of living and *recently* dead biological material as an energy source
  - Ultimately dependent on the capture of solar energy and conversion to a chemical (carbohydrate) fuel
  - Theoretically it is a *carbon neutral* and renewable source of energy
- How it works?
  - Traditional: forest management, using wood as fuel
  - Use of biodegradable waste
    - Examples: manure, crop residue, sewage, municipal solid waste
  - Recent interest in agricultural production of **energy crops**
    - Should be high yield and low maintenance
    - Examples: corn, sugarcane, switchgrass, hemp, willow, palm oil, rapeseed, and many others
    - Does not have to be a food crop
    - Recent interest in bioengineered (GM) plants as fuel sources
  - Production of a liquid or gaseous **biofuel**
    - *Biogas* due to the breakdown of biomass in the absence of O<sub>2</sub>
      - Includes capture of landfill methane
    - *Bioethanol* from fermentation, often from corn. Cellulosic bioethanol is usually from a grass (switchgrass)
    - *Biodiesel* from rapeseed and other sources

# Biomass Energy

- Carbon neutral
  - CO<sub>2</sub> ultimately released in energy generation is *recently* captured and so ideally does not change total atmospheric levels
  - *Carbon leaks* can result in a net increase in CO<sub>2</sub> levels
  - Sequestration in soil can result in a net *decrease* in CO<sub>2</sub> levels



# Biomass Energy

- Advantages
  - Versatile
  - Renewable
  - No net CO<sub>2</sub> emissions (ideally)
  - Emits less SO<sub>2</sub> and NO<sub>x</sub> than fossil fuels
- Disadvantages
  - Low energy density/yield
    - In some cases (eg, corn-derived bioethanol) may yield no net energy
  - Land conversion
    - Biodiversity loss
    - Possible decrease in agricultural food productivity
  - Usual problems associated with intensive agriculture
    - Nutrient pollution
    - Soil depletion
    - Soil erosion
    - Other water pollution problems

# Geothermal Energy

- How it works
  - Geothermal power plants
    - Use earth's heat to power steam turbines
  - Geothermal direct use
    - Use hot springs (etc) as heat source
  - Geothermal heat pumps
- Advantages
  - Renewable
  - Easy to exploit in some cases
  - CO<sub>2</sub> production less than with fossil fuels
  - High net energy yield
- Disadvantages
  - Not available everywhere
  - H<sub>2</sub>S pollution
  - Produces some water pollution (somewhat similar to mining)

# Radiant Solar Energy

- How it works
  - Solar power plants
    - Steam produced to turn turbine
  - Solar heating
    - Active and passive systems
  - Photovoltaic cells
    - “Solar batteries” use special semiconductors
- Advantages
  - Renewable and free
  - High energy yield
  - A very clean source of energy
    - No air/water pollution during operation
  - Low operating costs
    - Will pay for themselves over time
- Disadvantages
  - Intermittent source
    - Energy storage issues
  - Low energy density
    - Requires pretty much land

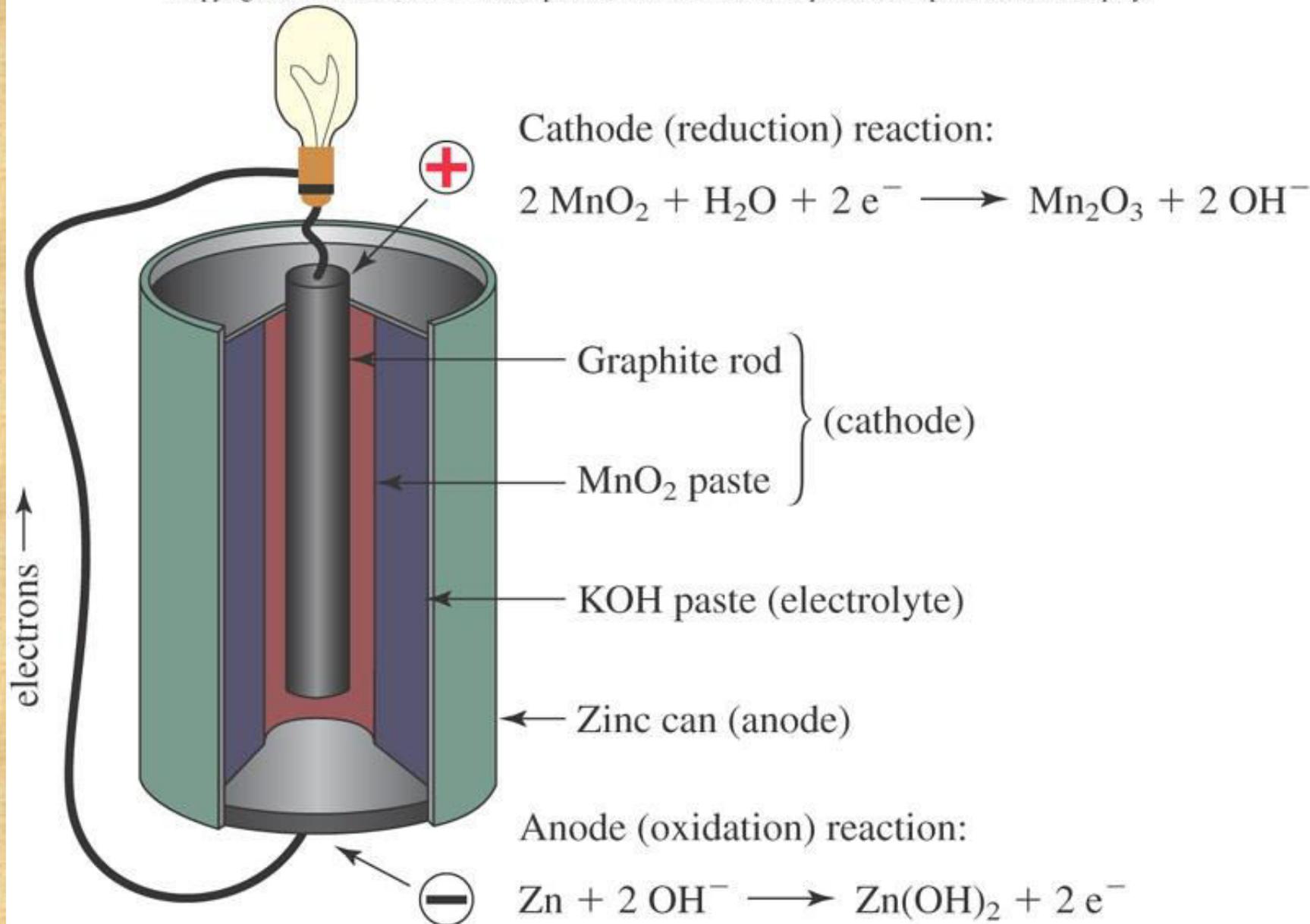
# Chemical Batteries

- *Lecture Questions*

- What are batteries and how do they work?
- What's the difference between a “regular” and a “rechargeable” battery? Why are rechargeable batteries sometimes referred to as “storage” batteries?
- Chemical batteries are based on reduction-oxidation (redox) reactions, which are reactions where electron transfer occurs.
  - The oxidation half-reaction occurs at the *anode*
  - Electrons flow from the anode, through an external circuit, and to the *cathode*, where the reduction half-reaction occurs
- Chemical batteries are a very efficient method of generating electricity
  - Efficiencies of 80% are regularly achieved
  - Significantly (2-3 times) more efficient than heat engines
- Rechargeable batteries can be hooked up to an external source of electricity to regenerate the redox reactants through electrolysis.
  - Rechargeable batteries thus provide a means of storing electricity in chemical form. They are thus sometimes called *storage batteries*.

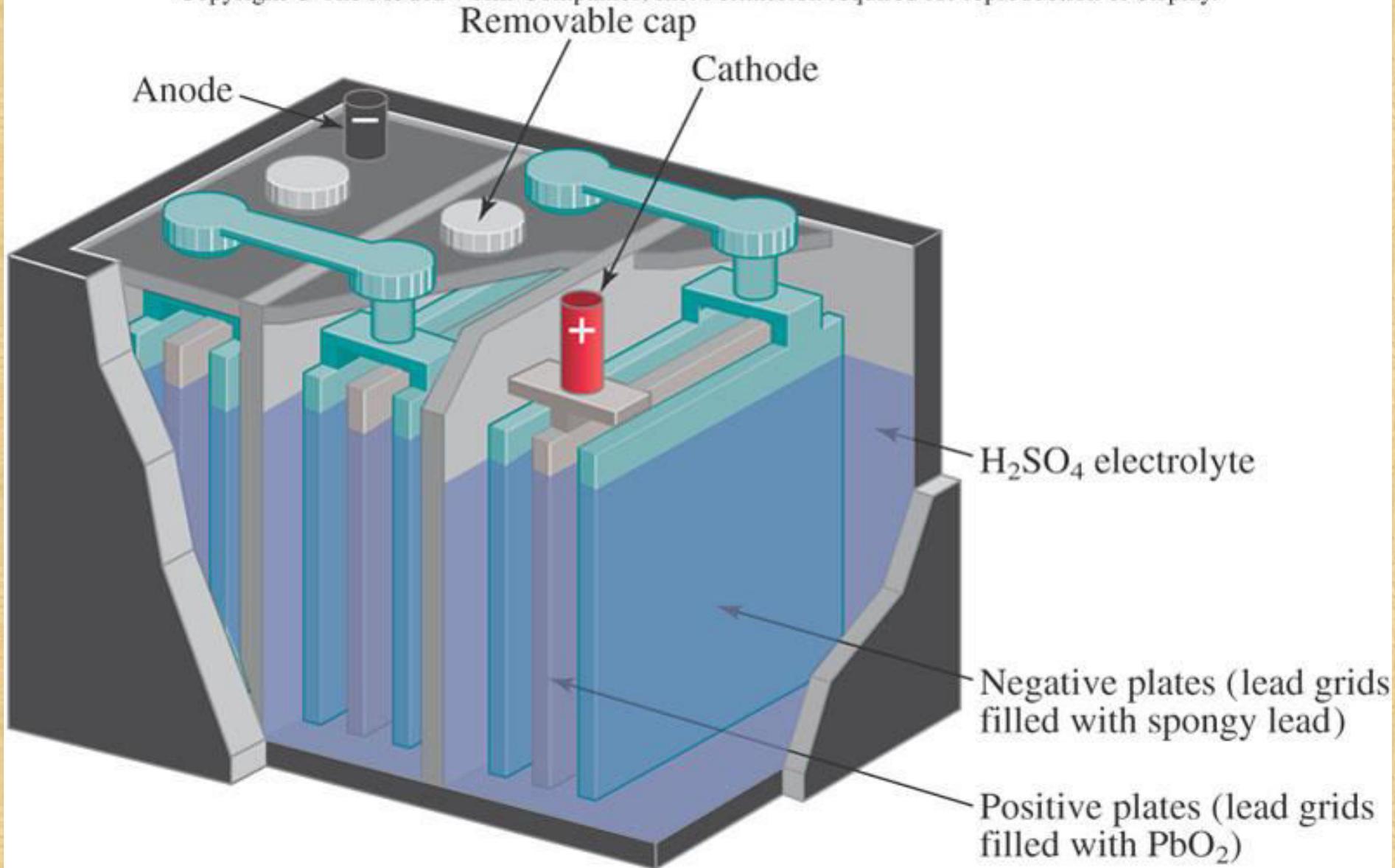
# The Alkaline Battery

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# The Lead Storage Battery

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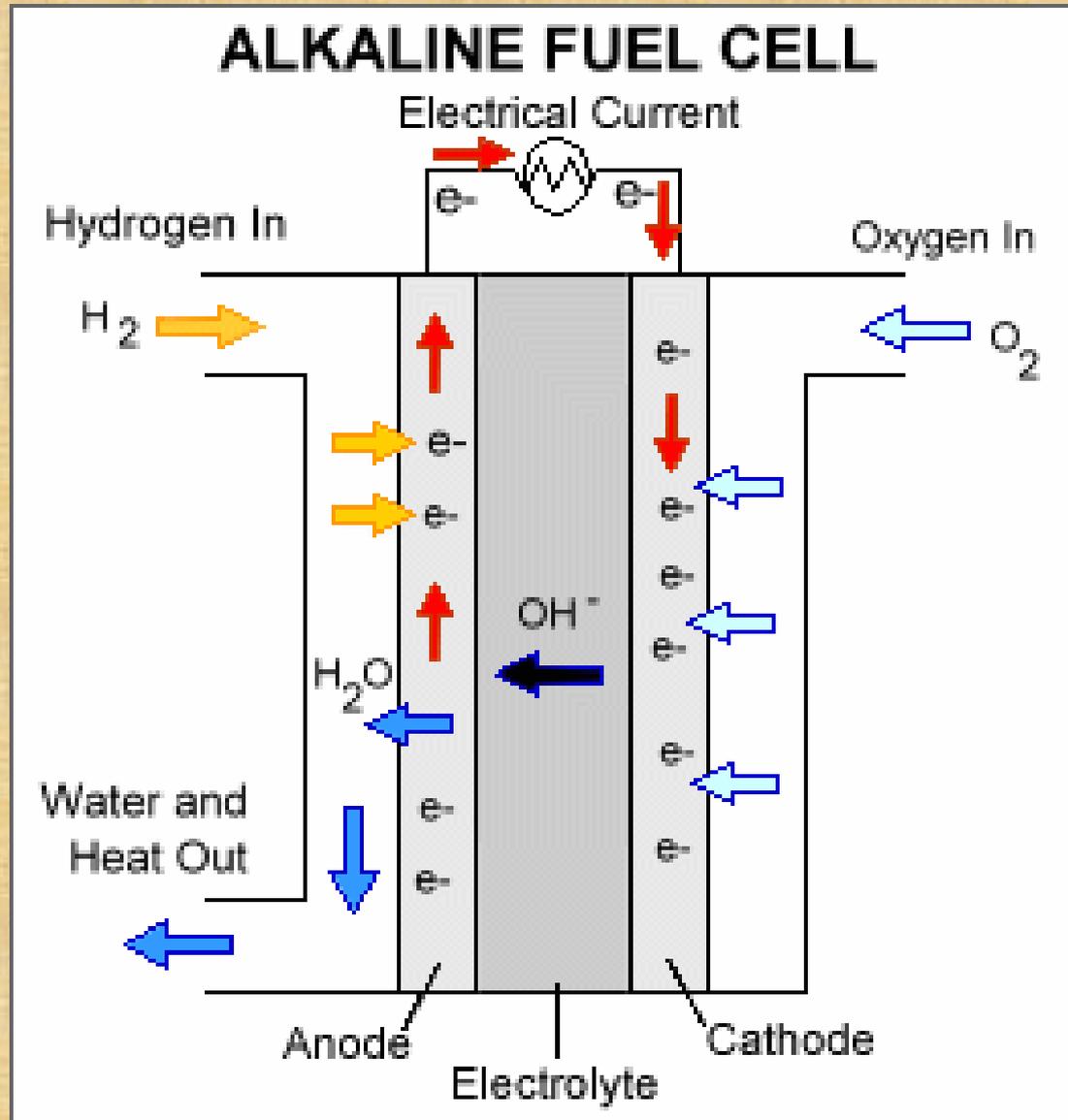


# Fuel Cells

- *Lecture Questions*

- What is a fuel cell and how does it work?
- What is *distributed generation*?
- A fuel cell is basically a battery in which the reactants are continually supplied to the electrodes, and the products are continually removed.
  - Much more efficient (2-3 times) than heat engines at generating electricity
  - Most common type of fuel cells based on hydrogen (there are others)
- Fuel cells are *scaleable*
  - Large ones can power homes or neighborhoods
  - Small ones can be used in appliances
  - Distributed generation is a decentralized power system consisting of hydrogen generators and fuel cells

# Alkaline Fuel Cell (AFC)



**THANKS**