ATM S 111, Global Warming

Alternative Energy

Jennifer Fletcher

Day 38: August 12, 2010

Assignments

- Read “Political Solutions” and “Technological Solutions” pp.286-332
- Be sure to let me know what your final paper/ project topic will be by Friday.
- If you’re writing a paper, a rough draft is due on Monday.

Alternative Energies

- We'll discuss these alternative energies
  - Wind
  - Solar
  - Nuclear
  - Geothermal
- Then we'll discuss a bit about biofuels and hydrogen fuel cells for transportation
- Next time we'll talk about geoengineering.

Wind Power

How is Wind Power Generated?

Wind blows past a turbine (like a propeller)

The turbine is connected to a generator, which transforms the mechanical energy of rotation into electrical energy.

A generator consists of copper wire and magnets in various configurations. A magnetic field that is moving generates a current in the wire. (This is called Faraday's Law, and is also important for electromagnetic radiation!)

http://www1.eere.energy.gov/windandhydro/wind_animation.html

How is Wind Power Generated?

Power produced is proportional to (wind speed) ^{3}

So it's not just average wind speed that matters

<u>example:</u>

average wind speed = 5 m/s

case 1: range of 4 to 6 m/s

average power ~ $1/2*4^3 + 1/2*6^3 = 140$ units

case 2: range of 1 to 9 m/s

average power ~ $1/2*1^3 + 1/2*9^3 = 365$ units

(multiply by the area of the blades to convert these "units" into Watts)

Gustier is better

Wind Power

- Rapidly growing in Europe (Denmark, Germany, Spain) & the US (TX, IA, CA, OR, WA)
  - Still very underutilized compared with capacity even in these countries
  - The global capacity for 80 m tall turbines is estimated to be ~70 TW, more than 5x the global energy demand. (1TW = 1 terawatt = 1,000,000,000,000 Watts; global demand ~12 TW)

- We are the Saudi Arabia of wind
  - Could provide 9 times US electricity usage just in **lower 48**

←← **Olddddddd** technology (drawing from 1325)

Main Problem: Intermittency

- Wind doesn't always blow
- Currently this isn't a huge problem because wind doesn't provide **most** of the electricity anywhere
  - Could become more of a problem in the future (may need nuclear/hydro/geothermal/etc plants as backup)
  - Denmark deals with this by selling excess power to Norway, Sweden, and Germany
- Having a grid with sufficiently large area can help ensure that the wind is blowing *somewhere*
- Solar power tends to be complementary to wind in midlatitudes (windier in winter, sunnier in summer)

Wild Horse Wind Farm

Location – 18 miles east of Ellensburg, Kittitas County; 127 miles southeast of Seattle

Land area – 9,000 acres

Start-up – December 2006

Turbines – 127

Power output – 229 MW at peak capacity; 642,000 MWh annual output (est.), enough to meet the total power needs of about 55,0 households

1 MW peak capacity needed for
1 Wal Mart store or 250 houses

Winds – must be at least 9 mph, peak capacity reached at 30 mph

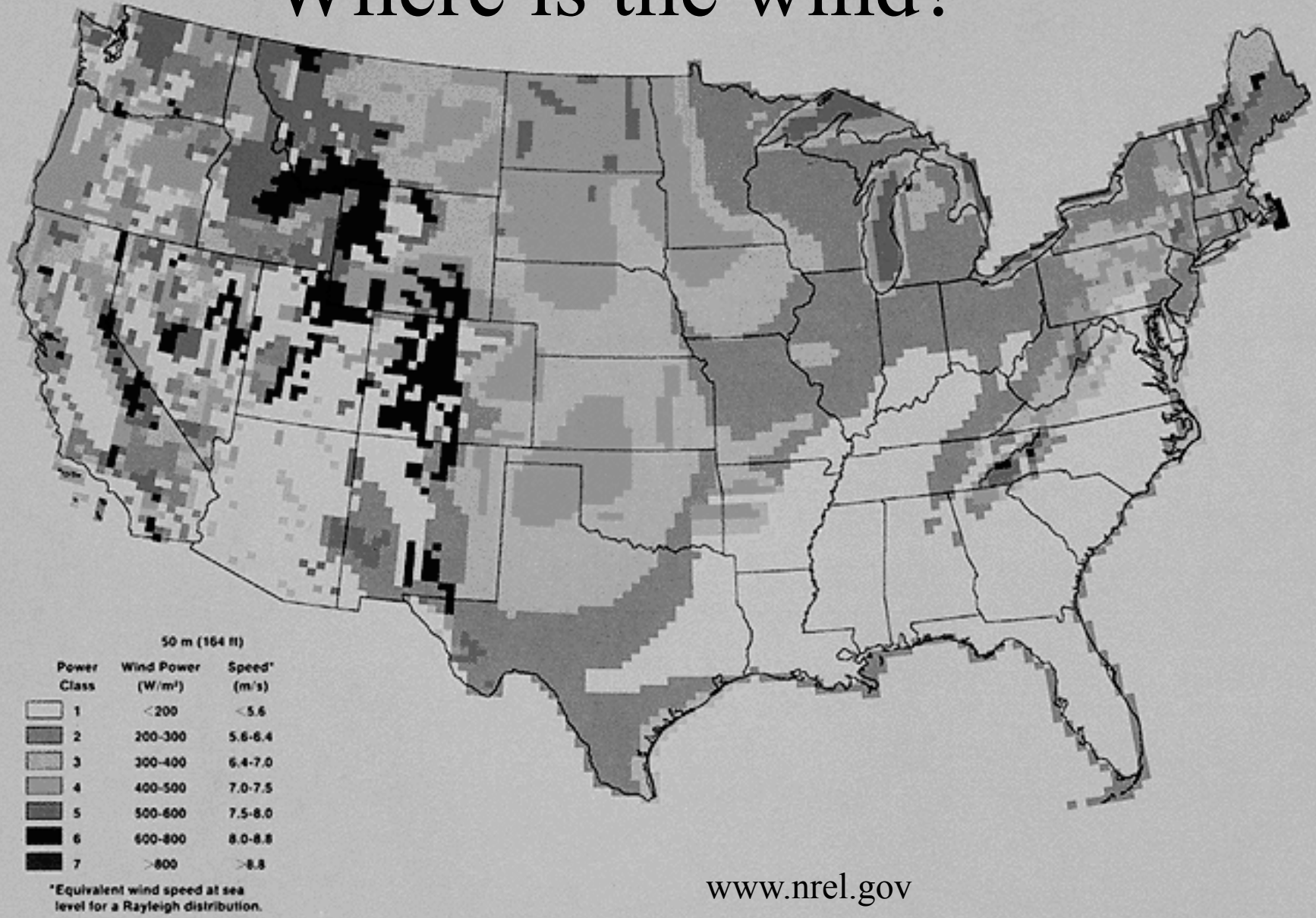
Produce electricity ¾ of the time at Wild Horse

Turbines - 351 feet tall from the ground to the tip of a vertical rotor blade; 223 tons total weight

Tower foundation – buried 25 to 32 feet (depending on bedrock depth) in up to 260 cubic yards of concrete;

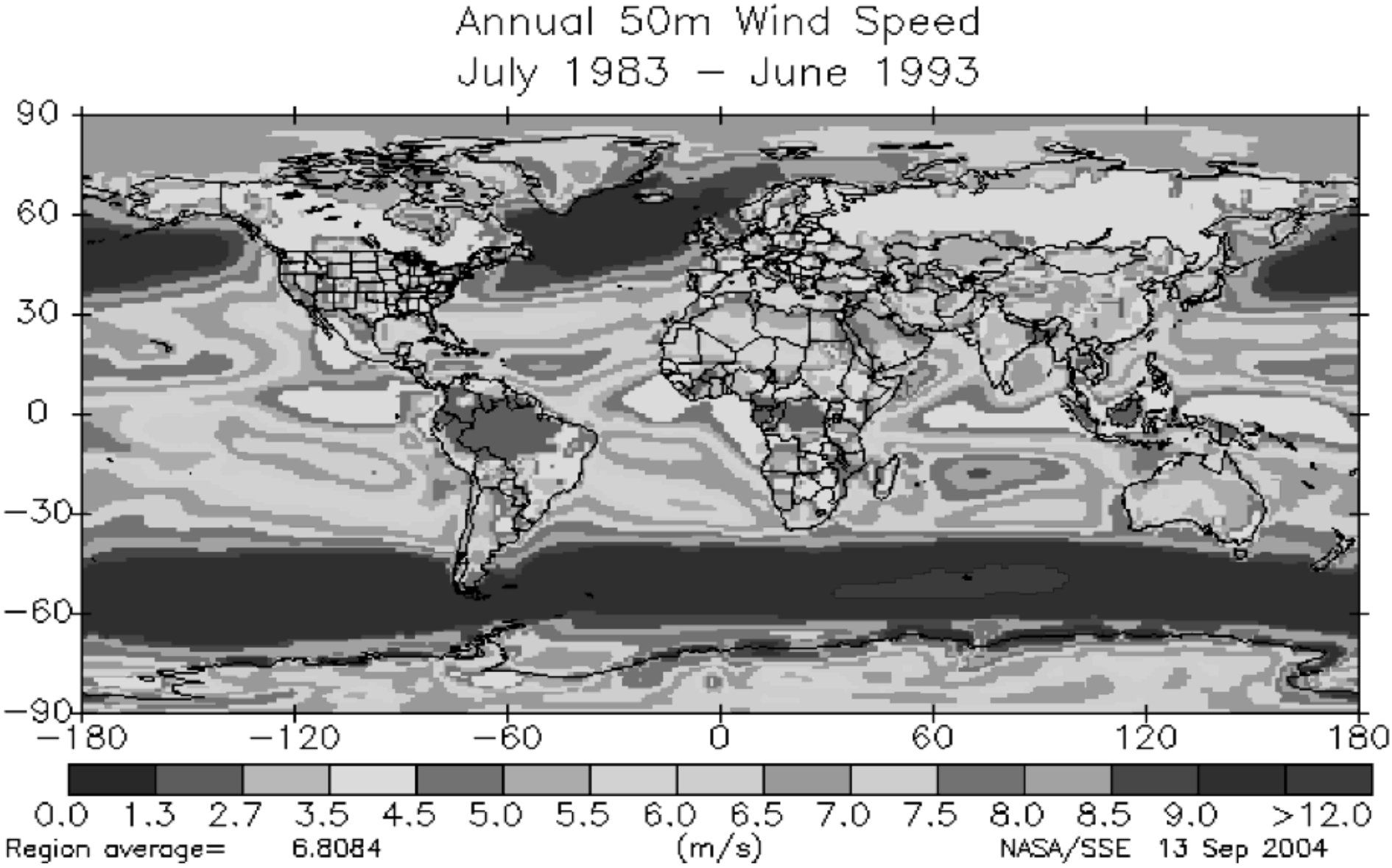
Generators –each produces up to 1.8 MW of power

Where is the wind?



www.nrel.gov

Where is the wind? Part 2



www.ocean.udel.edu

Pros

- Produces **no greenhouse gases** after windmill is constructed
- Decentralized production
- Moderately priced in the long term compared to fossil fuel
- Can use land underneath

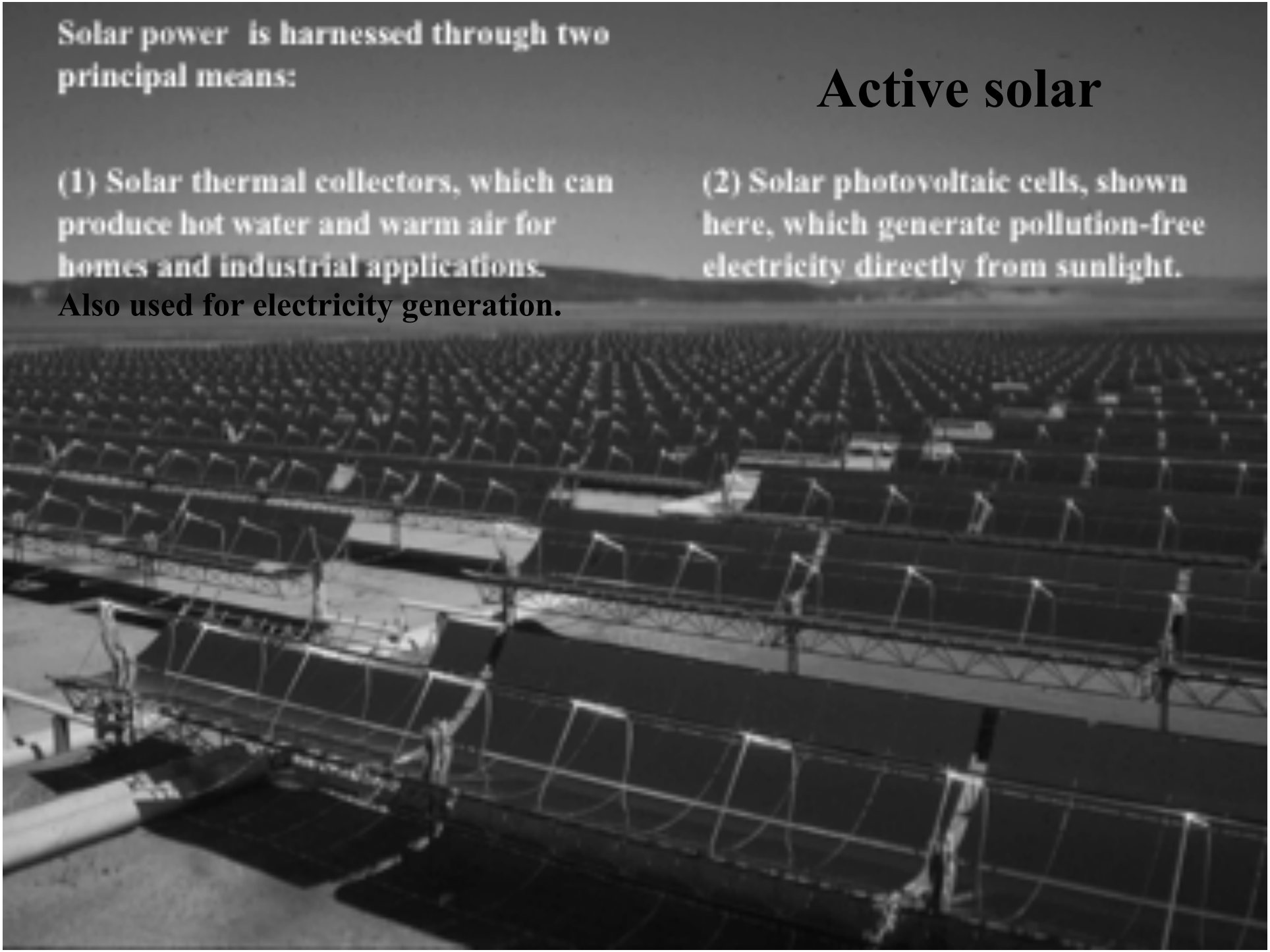
Cons

- Intermittent
- Not available everywhere
- Obstructs views/noise paranoia
- Hazard to birds? (probably not if placed away from migration zones)
- Requires large area

Solar Power

Passive Solar

- Passive solar: doesn't use mechanical or electrical equipment
  - Uses sunlight to reduce heating/lighting/ventilation costs
  - E.g., south-facing windows (in Northern Hemisphere) for more winter sunlight


Solar power is harnessed through two principal means:
Active solar
(1) Solar thermal collectors, which can produce hot water and warm air for homes and industrial applications.
(2) Solar photovoltaic cells, shown here, which generate pollution-free electricity directly from sunlight.
Also used for electricity generation.

Type 1: Solar Power Towers

- "Power tower" plant outside Madrid: mirrors heat **steam** in the central tower that drives a **turbine** (11 MW peak)

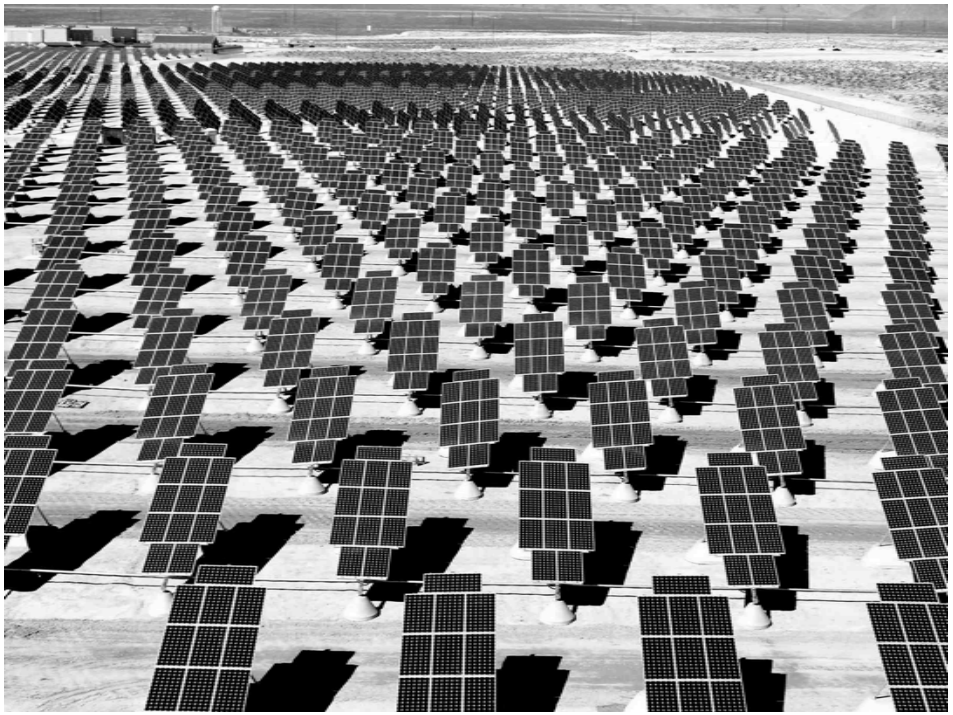
Photovoltaics

- "Photovoltaic" solar cells: light excites electrons in some materials and creates a current.
- Growing rapidly in Europe and Japan
- **Expense** is an issue: uses pricey raw materials
  - Subsidies are key now to make these economically viable
  - Prices are falling though
- Especially good for

  developing countries

  (can be installed one

  house at a time)



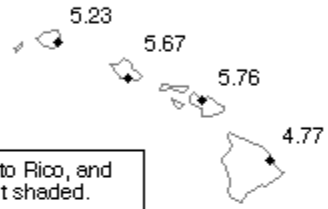
Average Daily Solar Radiation Per Month

ANNUAL

Flat Plate Tilted South at Latitude

Alaska

Hawaii



Hawaii, Puerto Rico, and Guam are not shaded.

San Juan, PR

Guam, PI

Collector Orientation

Flat-plate collector facing south at fixed tilt equal to the latitude of the site: Capturing the maximum amount of solar radiation throughout the year can be achieved using a tilt angle approximately equal to the site's latitude.

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB.

Maps of average values are produced by averaging all 30 years of data for each site. Maps of maximum and minimum values are composites of specific months and years for which each site achieved its maximum or minimum amounts of solar radiation.

Though useful for identifying general trends, this map should be used with caution for site-specific resource evaluations because variations in solar radiation not reflected in the maps can exist, introducing uncertainty into resource estimates.

Maps are not drawn to scale.

NREL

National Renewable Energy Laboratory
Resource Assessment Program

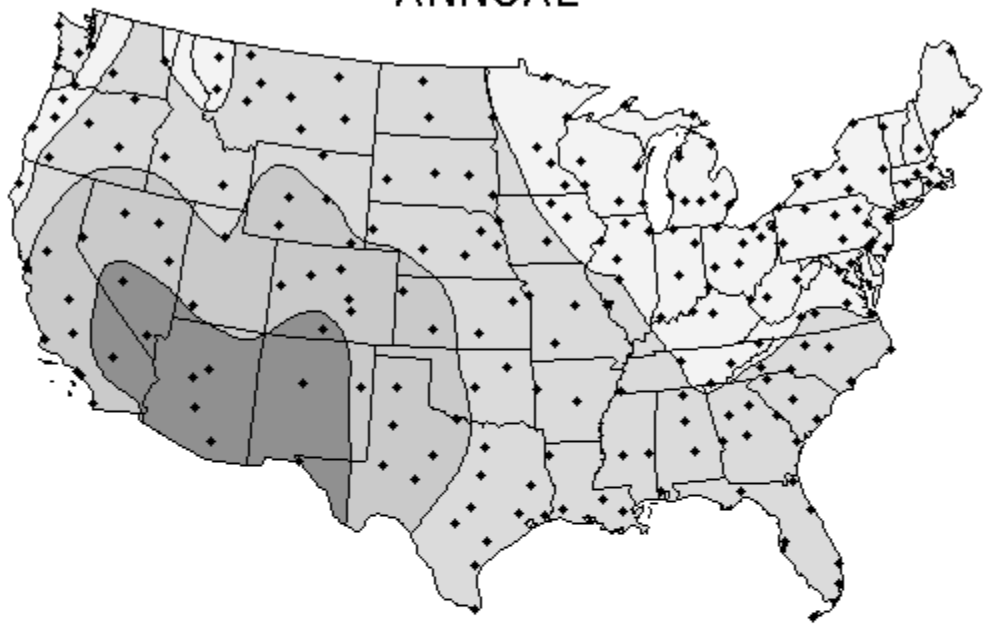
kWh/m^2/day

- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none

FLATA13-208

Average Daily Solar Radiation Per Month

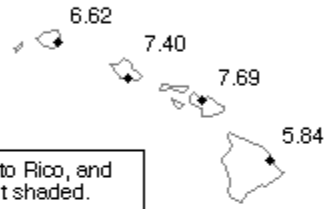
ANNUAL



North-South Axis Tracking Flat Plate Tilted at Latitude

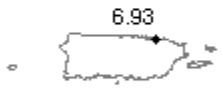
Alaska

Hawaii



Hawaii, Puerto Rico, and Guam are not shaded.

San Juan, PR



Guam, PI

Collector Orientation

One-axis tracking flat-plate collector with axis oriented north-south at a tilt angle equal to the site's latitude: To achieve maximum annual solar radiation, a tilt angle approximately equal to the site's latitude is recommended.

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB.

Maps of average values are produced by averaging all 30 years of data for each site. Maps of maximum and minimum values are composites of specific months and years for which each site achieved its maximum or minimum amounts of solar radiation.

Though useful for identifying general trends, this map should be used with caution for site-specific resource evaluations because variations in solar radiation not reflected in the maps can exist, introducing uncertainty into resource estimates.

Maps are not drawn to scale.

NREL

National Renewable Energy Laboratory
Resource Assessment Program

kWh/m^2/day

- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none

FXLTA13-442

Pros

- Produces no greenhouse gases after panel is installed
- Unlimited
- Long lasting (low maintenance cost)
- Peak production in-sync with demand (we don't need as much power at night)
- Decentralized production

Cons

- Expensive now
- Somewhat limited by location (deserts are gold mines for solar energy, but storing/transporting the power is expensive/inefficient)

Geothermal Power

Geothermal Power

- Taps into hot rocks under the surface of the Earth
  - This heats water, makes steam to turn turbines
- US is top producer (2.5 GW) in terms of total capacity (CA, NV, UT)
- Over 15% of the electricity generation in Iceland, Philippines, El Salvador, Costa Rica, and Kenya
- Very **steady** source (no problems with intermittency)

Pros

- Reliable supply
- Relatively simple facilities
- Inexpensive
- Small land footprint compared to wind and solar

Cons

- Regionally limited
- Releases a little CO_2 and other more harmful gases from ground
- Enhanced geothermal systems have caused seismic activity during construction

Nuclear Power

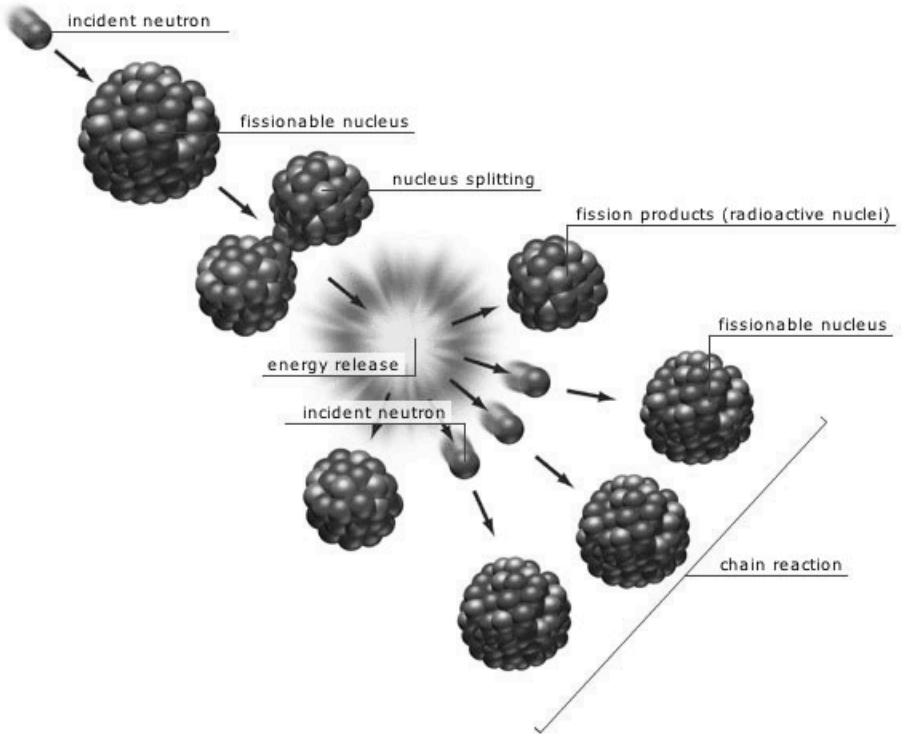
How is Nuclear Power Generated?

One way to capture this energy is to:

1) heat water

2) which makes steam

3) which can turn a turbine.

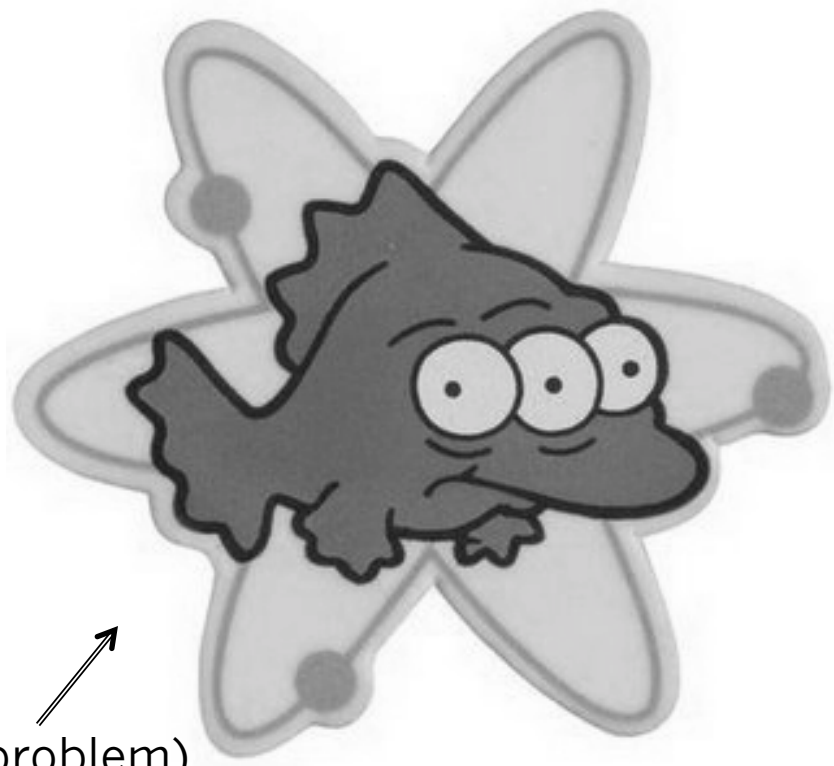


Nuclear Power

- Huge in France (80% of electricity there)
- Over 100 plants in the US
  - No new constructions since 1970s
  - Obama administration recently approved $8 billion for loans for new plants
- Many see a “nuclear renaissance” to help move towards carbon zero energy

Nuclear Power Problems

- New plant construction is rather expensive (~$10 billion)
- Waste disposal remains an issue
  - Highly radioactive material is produced that must be kept away from people
  - Short term storage on-site, but long term storage?
  - **Reprocessing** can help but this produces plutonium (can be used in weapons)



(not a problem)

Pros

- Produces no greenhouse gases
- Available 24 hrs/day
- Plenty of Uranium in US

Cons

- Expensive to build facilities
- Storage of extremely hazardous radioactive wastes that won't be safe for ~10,000 years.
- Requires lots of water
- Relationship to weapons (concerns about proliferation)

At this point in history, we have no real substitutes for oil in global transport…

We are working on some (e.g. hydrogen), but they are still years away.

Biofuels are likely to only be a temporary measure

Biodiesel

What is Ethanol?

- Ethyl Alcohol (the drinkable kind of alcohol)
- Produced by fermentation (using carbohydrates and yeast) or as a petrochemical.
- Sweet, simple carbohydrates ferment most easily (cane sugar is best, wood pulp is harder)

Ethanol Here and Worldwide

- Huge in Brazil (25% of their fuel)
  - From **sugar cane**
- We make more in the US, but from **corn**
  - Much less efficient than sugar cane – high carbon footprint (especially if land is deforested to grow it!)
- Cellulosic ethanol (e.g., from switchgrass) would be ***much better*** for carbon footprint
  - Easy to grow, doesn't require as much plowing, etc
  - Harder to get to ferment though (more expensive)

What is Biodiesel?

- Methyl or ethyl esters
- Formed by *transesterfication*:

  alcohol + oil --> less alcohol + biodiesel + fertilizer + glycerin
- Oil source: soybean oil, canola oil, restaurant grease

  biodiesel smells like french fries because esters are aromatic!

The Biofuel Cycle

CO_2

Is this C cycle closed or is there a 'leak' of C to the atmosphere?

Biodiesel

Fermentation and/ or transesterfication
oil, alcohol

Biofuel Use Today

in 2008, Americans consumed 9.6 billion gallons of ethanol, which reduced gasoline consumption by less than 5%

Most gasoline has some ethanol in it

E10 is Gasoline with 10% ethanol content by volume. E85 is 85% ethanol and 15% gasoline, and it is mostly sold in the Midwest.

The energy content of ethanol is about 33% less than “pure” gasoline, so your vehicle mileage may decrease by up to 3.3% when using E10.

Currently, you must have a “flex-fuel” vehicle to use gasoline with an ethanol content greater than 10% because ethanol takes more energy to vaporize. Can be hard to start in the cold

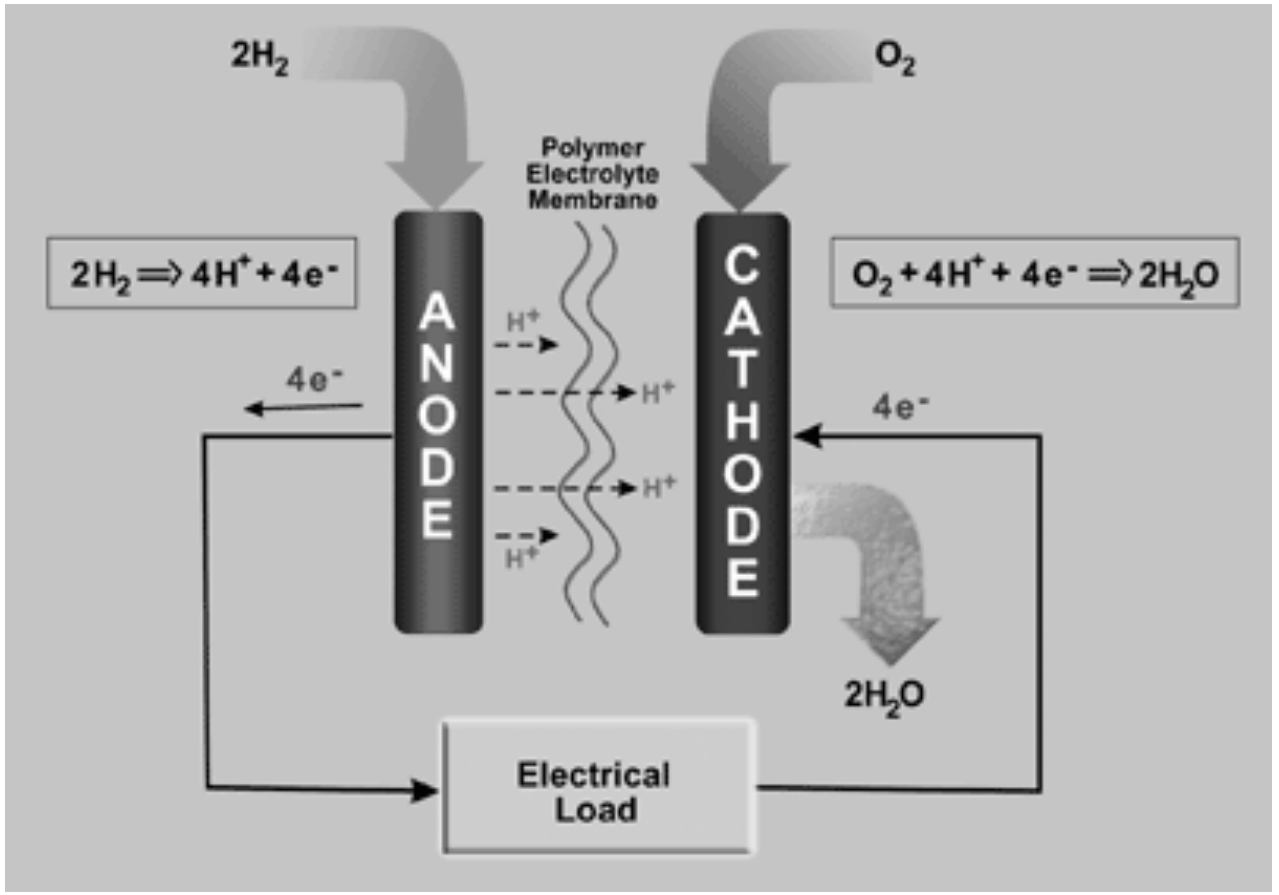
Pros

- Reduces NET CO_2 emissions
- Better for human health reduced carbon monoxide and particulate emissions.
- Less smog potential reduced unburned hydrocarbon emissions
- Reduced acid rain potential no sulfate emissions
- Energy independence

Cons

- May be worse for human health in some ways via emissions of ozone-creating chemicals
- Expensive
- Less land for food production people compete with machines for food
- Pure/high ethanol is not approved for most cars (okay as an additive)

Hydrogen Fuel Cells – make electricity



Like a battery but uses oxygen from the air
Needs a steady supply of the fuel, which is H_2

How does it work?

$2H_2 + O_2 \rightarrow 2H_2O + \text{energy}$

Sounds GREAT! Nothing bad in that equation!

Is there a catch?

The Catches

- Where do you get H_2?
  - not naturally occurring in large quantities
- H_2 can be generated via electrolysis
  - $2H_2O$ + energy --> H_2 + $2O_2$
  - Requires lots of energy
- H_2 can be generated from methane
  - requires energy and produces CO_2
- How is H_2 stored? it takes up a lot of space
  - Fuel tank many times bigger than car
  - Transport may be difficult too

Hydrogen is a carrier of energy, not a source

The Catches

- Joseph Romm (Assistant Secretary in the Dept of Energy in 1990s) says, "[the] hydrogen car is one of the least efficient, most expensive ways to reduce greenhouse gases."

- Many have argued that if we're going to use (renewable) energy to make hydrogen for fuel cells, we might as well just use that energy to power up batteries for cars instead.

- Last year, the Dept of Energy cut off research funding for hydrogen fueled cars.

Summary

- Alternative energy: ways to produce power (mostly electricity or to run cars) that reduce greenhouse gas emissions.
  - A lot of alternative energies (esp wind and solar) have problems with intermittency and need to be used in combination with others.
  - Biofuels come with new sets of health/food security issues.
  - Hydrogen cars are looking less and less likely – battery operated cars will probably be the best green option for transportation.

- Other technical solutions: geoengineering
  - These are methods for removing CO_2 from the atmosphere or altering earth's energy balance so that the greater CO_2 doesn't matter as much.
  - We'll discuss this next time.