1

Why sustainability?

- Sustainability: managing Earth's resources in such a way that they will not be depleted for future generations
- The basic necessity for environmental health and the future of humanity on Earth

2

Renewable Energy and Resources

- Anything that is not finite in its amount
- *Potentially* renewable: materials that are renewable as long as we do not overconsume
  - Biofuels, biomass, etc.
- Nondepletable: energy sources that we physically cannot exhaust or won't be exhausted within foreseeable human existence
  - Sun, wind, Earth heat, etc.

3

Energy Conservation

- Using less energy and researching ways to accomplish this
- May be technological but often social initiatives
- Many approaches for this—often government run or funded
  - Incentives (tax rebates for solar panels, for example)
  - Penalties (carbon tax, energy taxes)
  - Increasing availability of more sustainable options like public transport

4

Energy Efficiency

- Obtaining the same amount of work/output from a lesser amount of energy
- Largely technology based
  - Energy Star
  - Example: Fluorescent vs. Incandescent light bulbs

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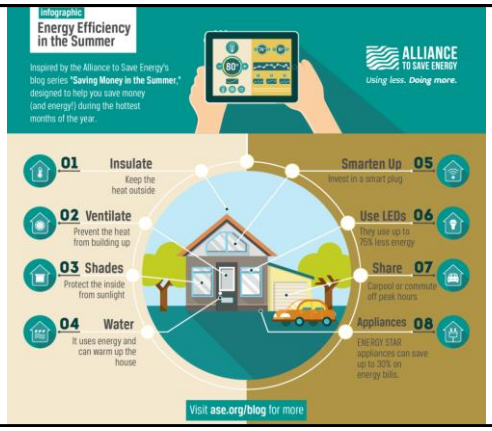

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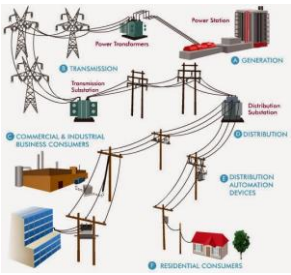
Challenges in achieving conservation…

- Electric availability needs to meet the greatest needs—**peak demand**
  - Means that systems are often over-designed and output way more than the average need
- BUT we still can't run out of energy at peak times→must reduce peak demand
- Energy is lost in transmission



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Sustainable Design

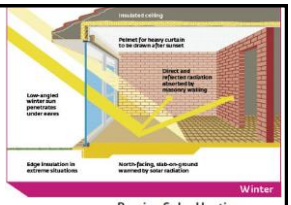
- Improving the design of a structure so that it wastes less energy or is more efficient
- Often relate to heating and cooling
- Can be materials based

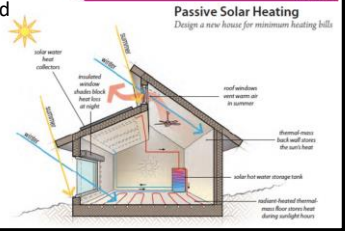
Bosco Verticale in Milan (>900 trees on this pair of condo towers!)

8

Passive solar design

- Using the sun to stabilize indoor temperatures
- Example: lighter or darker roofs depending on climate, double-paned windows, shades
- Thermal inertia: a material's ability to retain a given temperature





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Sustainable Energy Technologies

- Any piece of tech that improves energy efficiency or conservation
- Almost exclusively rely on renewable resources or natural cycles for a source of energy

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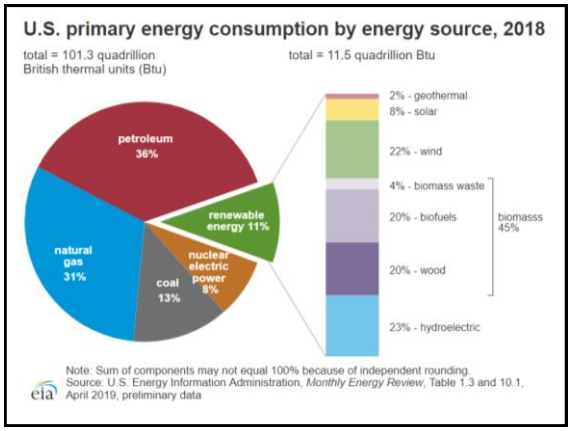

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Biomass

- Taking living or once living portions of the biosphere and burning them for combustion energy
- Trees, crop residues, bush fuel, etc. are all considered **modern carbon** as opposed to the fossil carbon of fossil fuels

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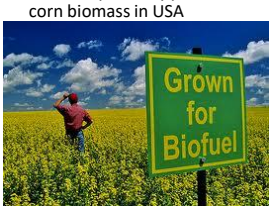
Biofuels

- Processed, liquid biomass in the form of biodiesel, ethanol, or a similar fuel
  - Made from plant carbohydrates
- Ethanol: one of the most common biofuels, primarily produced from corn biomass in USA



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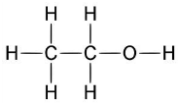
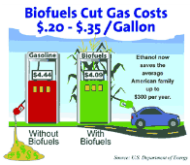
Ethanol



- Biggest producer is US (corn), second is Brazil (sugarcane)
  - US produced 16 billion gallons in 2018
- Almost all gas in the US is E-10--10% ethanol (gasahol).
- E-85 is a fuel that is 51-83% ethanol and made available for special flex-fuel vehicles



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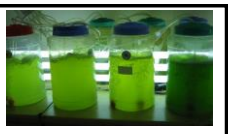
Biofuels: Advantages



- Renewable
- Sugar cane in particular is often harvested by hand, so less FF input
- Ethanol burns cleaner with fewer pollutants than petroleum
- Huge potential with cellulosic ethanol
  - Cellulose from algae, which also bioremediates
  - Fewer fertilisers
  - GMO plants that grow quick or on degraded land

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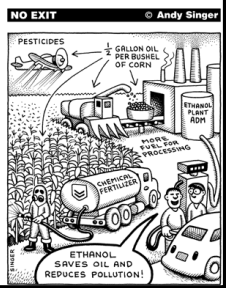
Biofuels: Disadvantages

- Lower energy output than FFs
- Still combusting a fuel (bad!)
- Air pollution
- Solid biomass fuels like wood and charcoal deforest and cause habitat destruction
- Production of some biofuels is at the expense of food production
- Need a carbon (often fossil fuel input) to create biofuels



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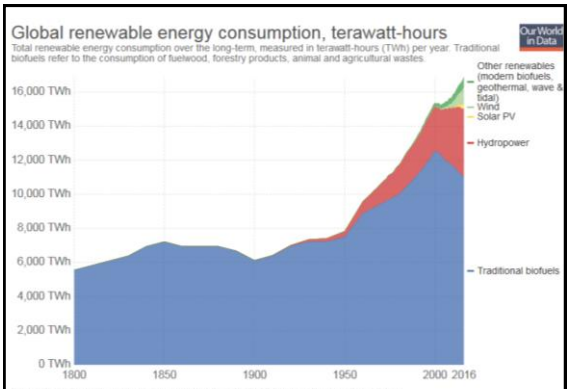

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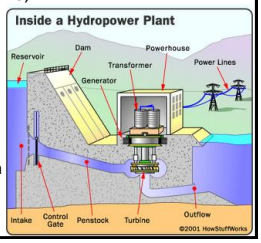
Hydroelectricity

- Generating electricity from the kinetic energy of moving water
- Water flows through turbines which turn to power generators
- 7% (2018) of the energy in the US, over half of which is in Washington, California, and Oregon
  - 40% of our domestic renewable energy
- ~17%(2017) of global energy and counting…
  - 4,036 TWh, or enough energy to power Gville for 6,500 years
- China is the biggest user, followed by Brazil. Rapidly growing in India and other LEDCs
- Three main types of HE power



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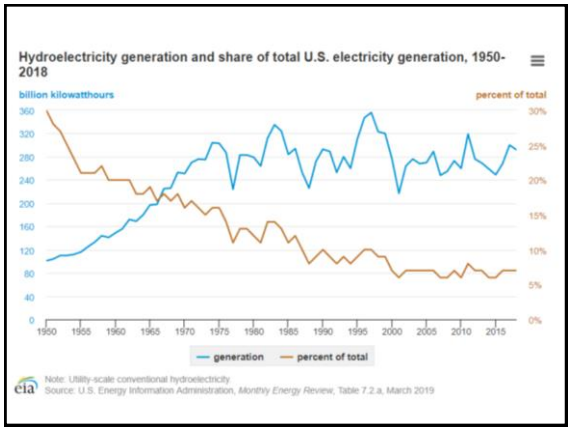

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Water Impoundment Systems

- Construction of a giant reservoir holds water back behind a dam, flooding upstream areas
- Pushes water through smaller channels via gravity to turn turbines
- Largest in US: Grand Coulee Dam in Washington (6,800 MW at peak)
- Largest in world: Three Gorges Dam on the Yangtze in China (22,500 MW/h at peak, 101.6 TWh in 2018)
  - 1 year would power Gville for 163

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Impoundment Pros

- Once built, require minimal FF inputs with long operating lifetime
- Reservoirs have economic and recreational purposes
- Down-stream flood control, irrigation, and water supply
- Can answer issues of peak power supply
  - "pumped storage"—during low demand water is pumped into a reservoir above the dam so that it may flow downhill during higher demand

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Impoundment Disadvantages

- Construction is a major sink for fossil fuels
- Flooding destroys natural and habited ecosystems
  - Covers forest and grasslands with water→ anaerobic decomp of plant matter releases methane
  - Altered river patterns can hurt downstream environments
  - Displaces people, could destroy cultural sites
- Siltation: buildup of sediments on the reservoir floor. Reservoirs might need to be dredged with machines that use fossil fuels)→ perhaps not so sustainable
- Block migratory pathways of some species
- Water rights issues

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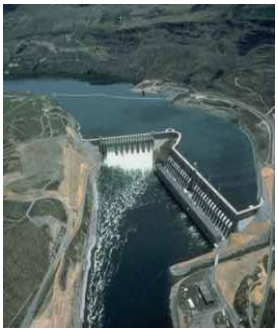
Run-of-the-river Systems

- Harness running rivers, streams, etc.
- Smaller scale with no reservoir
- Pros: Do not rely on extensive damming, so little upstream flooding
- Cons: Reliance on natural flow means you might lose electricity in the dry season



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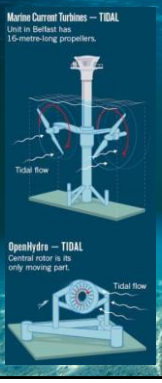
Tidal Energy



- Harnesses tidal flow to generate electricity
- Windmill like structures are turned to power generators
- Pros: Since tides come in and out constantly, power plants can take in energy both ways
- Cons: Not useful for much of the world because tidal differences are not great enough
- Roosevelt Island in NYC = first in USA

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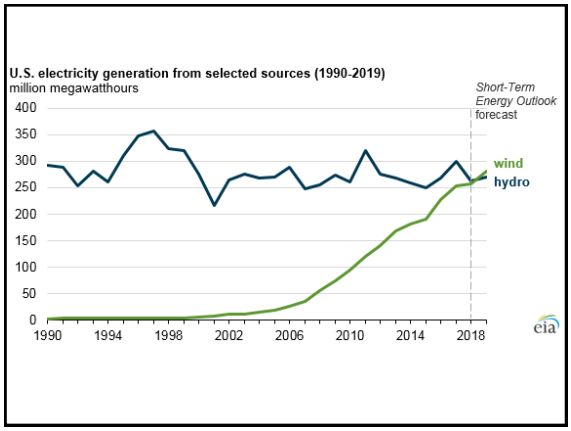

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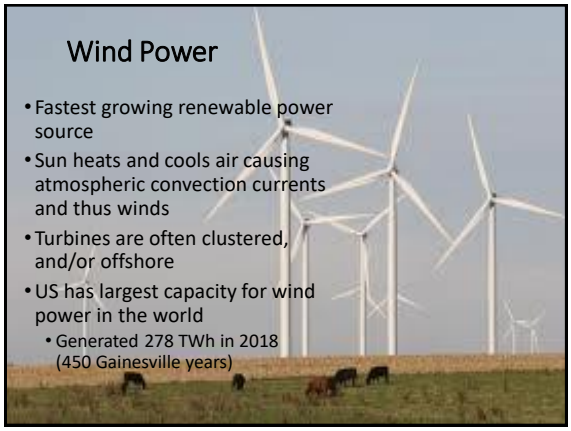

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Wind Advantages

- Nondepletable and sustainable
- Emission free, clean energy
- Cost effective
- Potential economic gains
  - Job creations
  - $20bil stake in US economy
- Can be installed many places, on many potential scales

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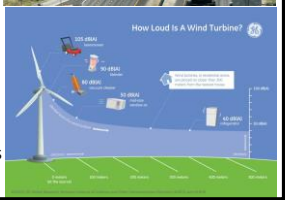
Wind Disadvantages

- Higher initial investments and may have long pay-off times
- Aesthetically displeasing, loud
- Transmission distances
- Can kill birds and bats who fly into them (Audubon 2018 estimates 140-328k bird deaths annually)
  - Many advances in recent years to improve this and FAR less than other bird loss causes



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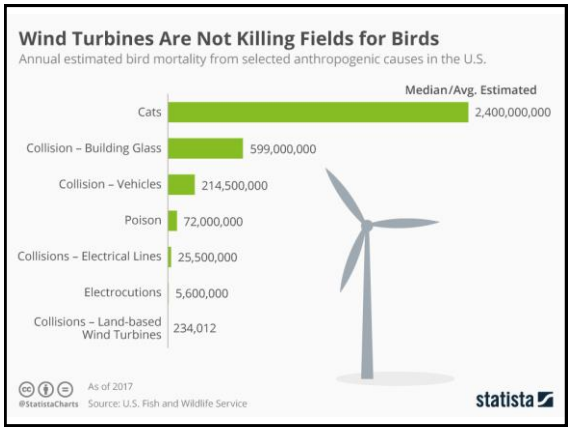

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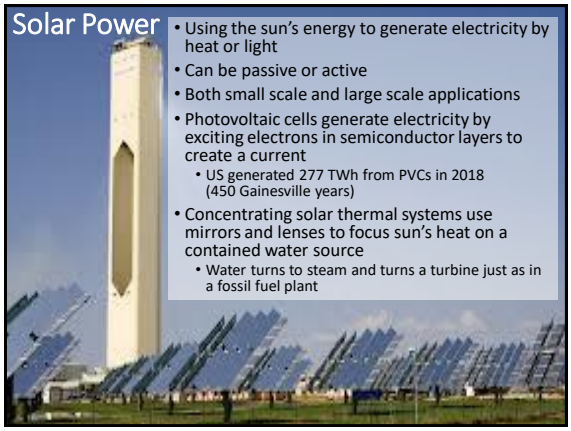

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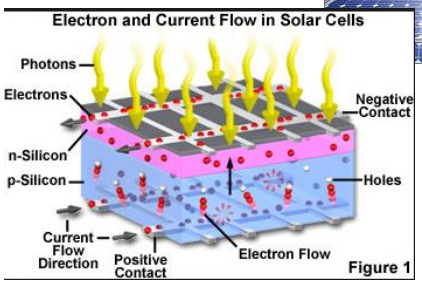
Photovoltaic Cells



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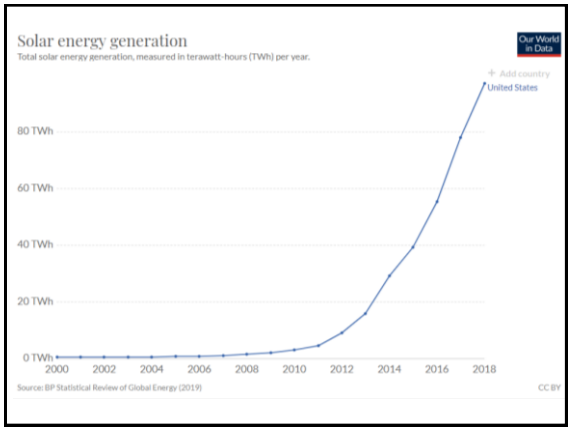

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A 110 MW/H solar plant in Israel's Negev desert

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Solar Advantages

- Almost no pollution in operation (no air, H2O, or CO2 pollutants), emission free
- Can be small-scale and economically feasible in many places (most have 1-4 year payback periods)
- Can produce electricity primarily during peak hours and lower peak demand—Earth receives 20,000x more solar energy than it could possibly use
- Low maintenance costs with long operating lives
- Huge potential for growth—China is currently the #1 producer and leads much investment
  - US implemented 25% tariffs against many solar tech imports in 2018

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Solar Disadvantages

- PV cells are expensive to make and install
- Toxic chemicals in manufacturing along with lots of water use
  - Rare earth elements and metalloids must be mined and refined—ultimately nonrenewable
- Variable availability with a need for batteries to store energy
  - Batteries take up space and can be pricey—Tesla Powerwall 2.0 is $7800 for hardware and hookup equipment alone

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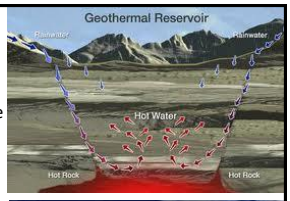
Geothermal Energy



- Heat from convection currents caused by radioactive decay in the Earth
- Can heat homes and heat water to turn turbines in electric plants alike
- Only 0.4% of our energy in US but we are the largest generator at 11 billion KWh
  - CA makes the most—6% of their power! NV has 10% of their power from geothermal
  - Highest % of overall power is Kenya—40%
- Ground source heat pumps good for transferring heat from Earth to homes

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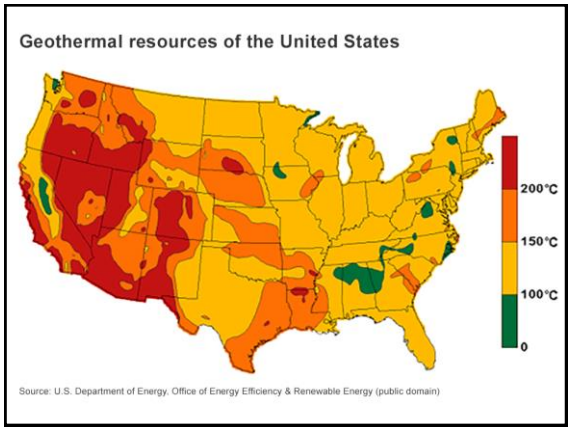

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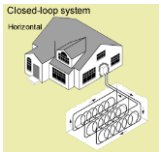
Geothermal Pros and Cons

- Pros: free source of energy once installed with no chance of depletion
  - Also uses less input energy than standard heating
- Cons: Primarily not available everywhere
  - Also can be rather expensive



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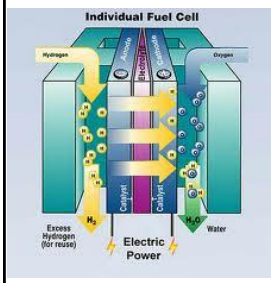
Hydrogen Fuel Cells



- Use hydrogen gas to create energy and water as waste
- Transfer of protons generates electricity
- Pros: More efficient than FFs with no carbon emissions—perfectly clean
  - Can regenerate H_2 by hydrolising water with an electric current ($H_2O \rightarrow H_2 + O_2$)
  - Potential vehicular fuel
- Cons: H_2 is rare on Earth, and requires electricity to generate from H_2O
  - Explosive gas
  - Need a way to store and distribute H_2

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Challenges for Sustainable Energy

- The electric grid: largely inefficient
  - Need to invest in new tech AND replace old tech
  - 5-10% of electricity is currently lost in transport
- Storing energy
  - Need more solutions to battery tech, even though things have improved immensely

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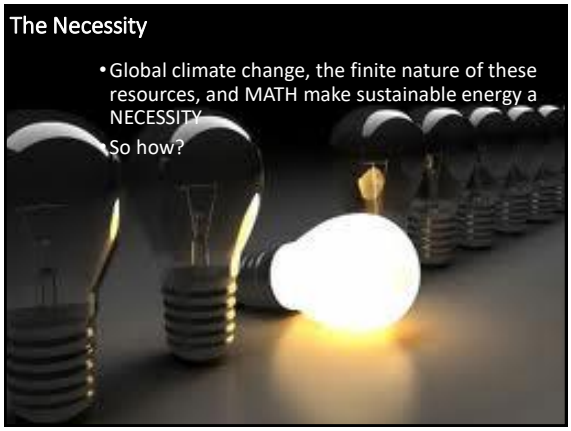
The Necessity

- Global climate change, the finite nature of these resources, and MATH make sustainable energy a NECESSITY
- So how?



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