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Powering the World

Power transmission lines near Anchorage, Alaska.

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Though our electricity system is highly complex, its basic principle is simple: 99 percent of our electricity comes from turning a generator.

We do that mostly by burning a resource like coal or natural gas to boil water, which makes steam, which turns a turbine, connected to a generator.

Heat from a nuclear reaction or a geothermal well are other ways to make steam and turn a generator.

Water held behind a dam, then released to flow through turbines, turns generators without having to produce steam.

All these generation systems produce emissions—like water vapor, CO_2 or other gases, particulates, or a small amount of nuclear waste.

And all of them are available on demand, which is very important, because we can't store electricity very well at scale. So it must be made when we need it.

Wind, too, turns a generator. It makes up about 1 percent of global power generation.

Solar, the only one to produce electricity without a generator, makes up another 1 percent.

Wind and solar produce no emissions. But they have other environmental impacts, in mining materials, manufacturing, the large amounts of land they occupy, and eventual disposal.

And because they make electricity only when the sun shines or the wind blows, we have to back them up with other power sources.

The modern world depends on our electricity system, and it's something we'll talk more about.

Bureau of Economic Geology

Background: Powering the World

Synopsis: We all depend on the electricity that comes from our light switches and the plugs in the wall, but where does all that power come from? It takes a lot of work to turn raw energy sources into power, but the basic principles behind making electricity can be seen in two easy recipes.

RECIPE 1: Electromagnetic inversion is the real workhorse for electricity generation.

1. **Convert ingredients:** Start from a variety of raw energy resources to create kinetic energy—the energy of a body in motion. Use turbines to convert any kind of kinetic energy into rotational kinetic energy.

- Combustion of coal, oil, or natural gas produces heat that turns water into steam used to turn turbines. Since these fuels are transportable for use on demand, they are always available, making them the most reliable baseload fuels for electric grids.
  - Coal is a solid fossil fuel.
    - The earliest coals were deposited about 300–350 million years ago in the Carboniferous period. Earth was covered in dense forests that flooded repeatedly with algae-rich waters, creating swampy bogs. Once buried and compressed, these deposits formed the rocks we call coal.
    - Coal is plentiful, globally distributed, and cheap, but it is a dirty fuel when burned since all the swamp materials get burned along with the carbon.
  - Oil is a liquid fossil fuel.
    - Although much of Earth's oil formed in the past 200 million years, oil in Australian rocks as old as 1.4 billion years formed from primitive algaes buried in Proterozoic lakebeds and seabeds.
    - Oil is the most compact and easily transported fuel, from pipelines to jet engines to our gas tanks. It has made modern transportation possible because of its portability, but it can also be used to produce electricity.
  - Natural gas is a gaseous fossil fuel.
    - Natural gas evolves from shale, coal, and oil under the right pressure and temperature conditions. It may be produced if oil deposits are heated to the point that they "crack" into natural gas underground. Natural gas deposits may also form instead of oil if the buried organics have a higher proportion of plant material than of algae.
    - Natural gas is a clean-burning fuel that is displacing coal as a less expensive alternative. Supplies are growing as shale drilling accelerates and technologies develop to liquefy or compress natural gas to make it more portable.
- Nuclear, geothermal, and concentrated solar plants also heat water to create steam that turns turbines.
  - Nuclear power requires very expensive infrastructure but is very inexpensive to keep online once it starts operating.
    - It can be used as a baseload fuel locally once the infrastructure is in place.
    - Nuclear accidents are infrequent but can be extremely dangerous, as we have seen in Chernobyl.
  - Geothermal power is geographically restricted and depends on high heat flow in Earth's crust.
    - It can be used as a local baseload source.
  - Concentrated solar power (CSP) is very clean power created by focusing the sun's rays on a central tower using mirrors.
    - It can't be used as a baseload source because it is only available during daylight hours, although some heat can be stored for use at night.
    - It requires large areas for deployment of mirrors.
- Other sources use natural power to create rotational energy.
  - Hydroelectric projects harness the gravitational pull of falling water, using turbines to create rotational energy.
    - These are dependable for baseload usage unless drought occurs.
  - Windmills capture the power of wind as rotational energy.
    - Wind can be intermittent so it can't be used as a baseload power source.

References: Powering the World

Energy Issues | SwitchEnergyProject.com
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Solar Basics | US Energy Information Administration

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2. **Spin:** Use generators to transform the rotational energy from any of these sources into electrical current using electromagnetic induction.

- In 1831, Michael Faraday discovered that using rotational energy to spin a coil of conductive wire inside a magnetic field produces an alternating current as the wire moves past the positive and negative poles of the magnet.

3. **Transmit:** Send the current along electrical transmission lines, but be sure to progressively step the voltage down on the way to your house to avoid a really shocking experience!

- In 1883, Nikola Tesla made it possible to transport alternating current over long distances by inventing the Tesla coil, a transformer that converts low voltages to high voltages and is still being used today. Alternating current (AC) is more easily transmitted over long distances than direct current (DC).

4. **Serves:** Most of the people in cities around the globe!

RECIPE 2: The **photoelectric effect**—the ability of matter to emit electrons when photons from sunlight hit its molecules—provides supplemental electricity from the sun.

1. **Absorb ingredients:** Use the abundant solar radiation that hits Earth's surface to produce photons.

- Earth receives more energy from the sun in a single hour than is used by the entire world in one year.
- Humans have used solar radiation for thousands of years for warmth and to grow food.
- Solar energy is intermittent; it is only available during the day so can't be used for "always available" baseload.

2. **Produce electrons:** Use photons from solar radiation to cause electrons to be bounced out of their orbits by the photoelectric effect.

- Albert Einstein didn't win the Nobel Prize for his Theory of Relativity, but he did win it in 1921 for explaining the photoelectric effect. This was a first step into physics at the molecular level—quantum physics.
- o Solar photovoltaic (PV) cells are constructed to absorb photons from solar radiation that bump electrons out of their orbits.

3. **Collect electrons:** Use solar PV cells to produce an electrical current.

- Solar PV cells are built with an electrical imbalance that herds electrons toward conductive plates in the cell, resulting in a direct electrical current.

4. **Convert to usable current:** Change the direct current into alternating current.

- Inverters change the direct current into an alternating current that can be used locally by appliances or transmitted into the electric grid.
- Solar PV cells can be used individually to power tiny things like watches, or they can be connected into panels or farms to create huge power sources.

5. **Serves:** Individuals, remote areas, and populations near solar farms during daylight.

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