

## Energy Sources

---

---

---

---

---

---

---

## Fossil Fuels

- Most common way of producing electricity
  - Coal 38%
  - Natural Gas 23%
  - Oil 3%
- The fuel is burned, and the thermal energy is used to power steam engines which drive the generators

Data source: <https://www.iea.org/weo2019/fuels/> (2018)

---

---

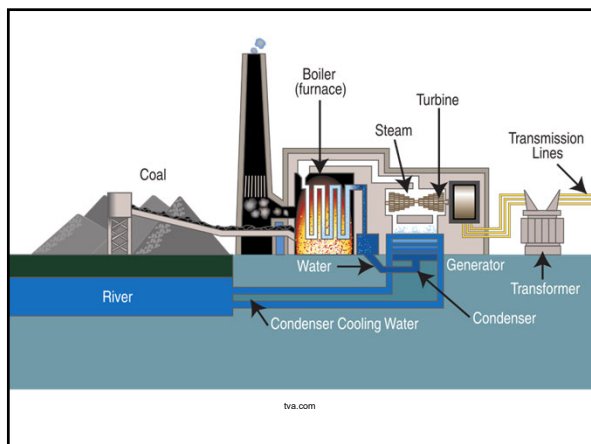
---

---

---

---

---



---

---

---

---

---

---

---

## Advantages

- Relatively cheap
- High energy density
- Variety of engines and devices use them directly and easily
- Extensive distribution network is in place

---

---

---

---

---

---

---

## Disadvantages

- Will run out
  - ~70 years for conventional oil and 250 – 350 years of coal
- Pollute the environment
  - The pollution comes from incomplete burning and from impurities in the fuel
  - Technology has greatly decreased the amount of harmful emissions from burning fossil fuels

---

---

---

---

---

---

---

- Emit greenhouse gases
  - That's what happens when you burn something
  - Human contributions to the amount of greenhouse gasses in the atmosphere is a very small proportion of natural contributions

---

---

---

---

---

---

---

## Hydroelectric Power

- Oldest and most established source of electrical power
- Power is generated from water falling over (or through) a turbine connected to a generator
- 16% of the world's electricity is hydroelectric

---

---

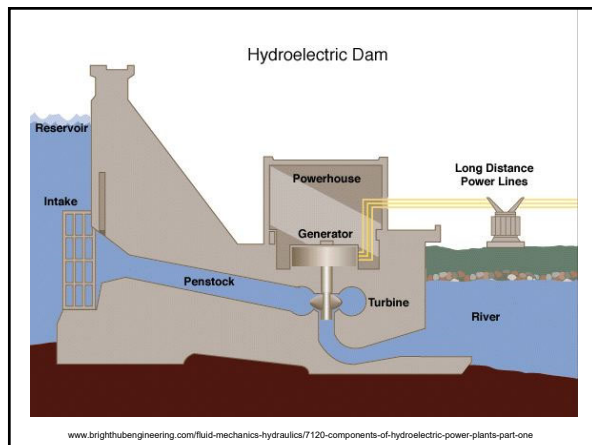
---

---

---

---

---



---

---

---

---

---

---

---

- A pumped storage system takes the water that flows through the turbine and pumps it back up to its original height
- This takes power and lowers the overall efficiency of the power plant
- This technique is used to store power until it is needed

---

---

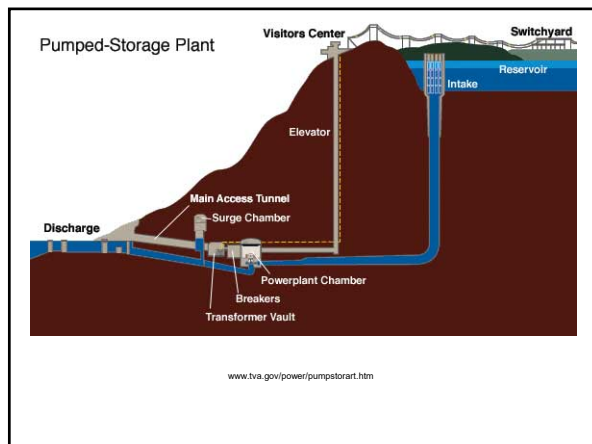
---

---

---

---

---




---

---

---

---

---

---

---

---

- Power produced is a result of a mass of water,  $m$ , falling from a height,  $h$ , during a period of time  $\Delta t$

$$P = \frac{mgh}{\Delta t}$$

But the volume of water is more important. So...

$$\rho = \frac{m}{V} \quad \text{or} \quad m = \rho V$$

---

---

---

---

---

---

---

---

$$P = \frac{\rho Vgh}{\Delta t}$$

$\frac{V}{\Delta t}$  is referred to as the volume flow rate,  $Q$

$$P = \rho Qgh$$

Note: This assumes 100% efficiency

---

---

---

---

---

---

---

---

## Advantages

- “Free”
  - Ignoring the cost of construction, equipment, and maintenance
- Inexhaustible
- Clean
  - Ignoring what happens during construction and the flooding that occurs

---

---

---

---

---

---

---

## Disadvantages

- Very dependent on location
- Requires drastic changes to the environment
  - Not necessarily a bad thing
- Initial costs high
  - This is not unique to hydroelectric dams

---

---

---

---

---

---

---

## Nuclear Power

- Nuclear fission produces thermal energy which is used to produce steam to drive generators
- 10% of electricity world wide is produced by nuclear power

---

---

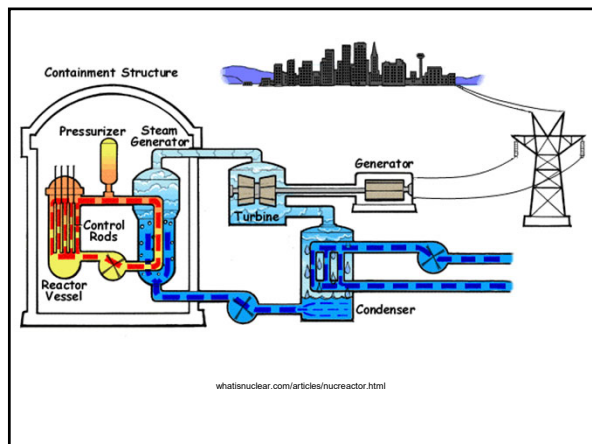
---

---

---

---

---



---

---

---

---

---

---

---

## Advantages

- High power output
- Large reserves of nuclear fuels
- No greenhouse gasses produced

---

---

---

---

---

---

---

## Disadvantages

- Radioactive waste products are difficult to dispose of
  - There is actually very little waste and governments have refused to pay for research into the long term storage and disposal of waste

---

---

---

---

---

---

---

- Major public health hazard should something go wrong
  - Longstanding myth
  - There have only been three major nuclear accidents (Three Mile Island, Chernobyl, Fukushima) and the resulting “damage” was completely contained; there was no wide spread environmental or human issues
- Problems associated with uranium mining
  - No more than any other mining operation

---

---

---

---

---

---

---

- Possibility of producing materials for nuclear weapons
  - This is a real concern if the reactor uses enriched uranium
  - This problem would be eliminated by using Thorium as a fuel

---

---

---

---

---

---

---

## Wind Power

- Windmills directly turn a generator
- 5% of the world's electricity is generated by wind
- The windmills used to produce a few megawatts of electricity are huge (vanes are larger than 30 m)
- Serious power production from wind requires constant wind speed of 6-14 ms<sup>-1</sup>

---

---

---

---

---

---

---



[www.theinnovationdiaries.com/1146/windmill-power/](http://www.theinnovationdiaries.com/1146/windmill-power/)

- A mass of air,  $m$ , passes through an area,  $A$ , with a velocity,  $v$ , in time  $\Delta t$
- The density of the air is  $\rho$
- In  $\Delta t$ , the wind travels a distance  $v\Delta t$ , giving a volume of  $Av\Delta t$
- The mass of air is thus  $\rho Av\Delta t$
- Calculating the kinetic energy of this air gives

$$\frac{1}{2}mv^2 = \frac{1}{2}(\rho Av\Delta t)v^2 = \frac{1}{2}\rho A\Delta tv^3$$

- The power generated by the wind turbine is therefore

$$P = \frac{1}{2}\rho Av^3$$

Note: This assumes that 100% of the wind's kinetic energy is converted to power.

(Only about 35-45% of the wind is actually captured by the windmill.)



## Advantages

- “Free”
  - Ignoring equipment and other costs
- Inexhaustible
- Clean
  - Ignoring manufacturing

---

---

---

---

---

---

---

## Disadvantages

- Works only if there is wind
  - And only if the wind’s velocity is in a specific range
- Aesthetically unpleasant
- Noise problems
  - The turbines produce a constant low frequency hum when they are in operation

---

---

---

---

---

---

---

- The initial and maintenance costs are high
  - D361 Wind Turbine (1kW peak power):  
\$11,000 USD (plus batteries, wiring, installation)  
Greenerenergy.ca
    - An average home uses ~1000 kWh/month with a daily peak or ~700W
- Kill bats and birds
  - US wind turbines kill 75 000 – 275 000 birds per year (some of these are protected species like bald eagles)

---

---

---

---

---

---

---

## Solar Power

- Solar Heating Panel
  - Sunlight heats water (or air) for heating a house
  - Normally used to heat water in a hot water tank

---

---

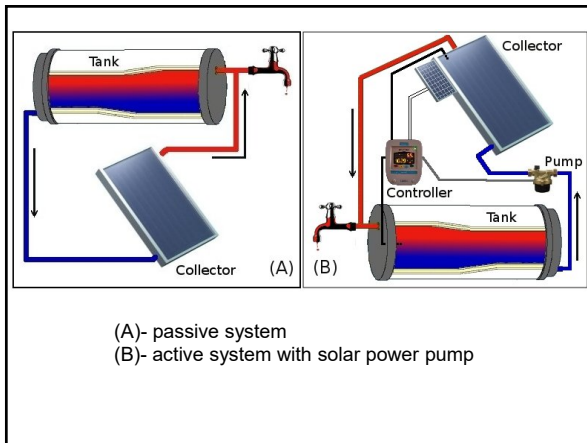
---

---

---

---

---



---

---

---

---

---

---

---

- Photovoltaic Cells
  - Developed in 1954 at Bell Laboratories
  - Used extensively in the space program to power satellites
  - Sunlight incident on the panels releases electrons and establishes a potential difference across the cell
  - Efficiency ~30%
  - 2% of electricity is generated by solar power worldwide

---

---

---

---

---

---

---



Solarkraftwerk Waldpolenz, the first Solar 40-MW CdTe PV Array installed by JUWI Group in Brandis, Germany (Photo courtesy of JUWI Group)

---

---

---

---

---

---

---

---

## Advantages

- “Free”
  - If we ignore the cost of all of the equipment
- Inexhaustible
  - Except when its night (or cloudy)
- Clean
  - Ignoring the manufacturing process and batteries that are necessary for storing power

---

---

---

---

---

---

---

---

## Disadvantages

- The sun is not always shining
  - Does not work when it is cloudy or night
- Low power output
  - ~30 V, ~7 A
  - Output is DC which must be converted to AC with an inverter

---

---

---

---

---

---

---

---

- Initial startup costs high

- 2.58 kW Roof Mount On/Off Grid Kit – Home

- Model: SFGT2.5XWAGM

- 2.58 kW solar array with roof / ground mount; 4.5 kW grid tie inverter; 60A charge controller; distribution panel; auto generator start; System control panel; inverter system comes pre-assembled and wired; 390 Ah (48VDC) 6V AGM maintenance free battery bank with cables and hardware; Shipping to nearest shipping depot

- \$24,199.00 CAD

solartrader.ca

---

---

---

---

---

---

---

---

- Requires large area

- The example system Solar Trader has 12 panels 59.1" x 39" for a total area of 192 sq ft (17.8 m<sup>2</sup>)

- Maintenance costs are high

- The battery bank in the example system lasts 8 years and then must be replaced at a cost of \$5600

---

---

---

---

---

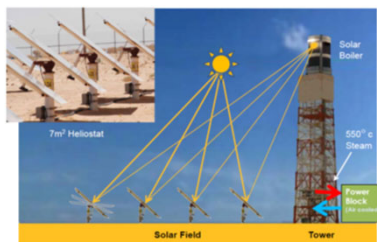
---

---

---

- Solar Thermal

- Mirrors focus sunlight onto boilers generating steam which drives a generator



www.energy.ca.gov/siting/meetings/2010-01-22\_meeting/presentations/BrightSource\_Energy-Ivanpah\_Project\_Overview\_2010-01-22.pdf

---

---

---

---

---

---

---

---



Aerial photograph of Ivanpah Solar Power Facility (Craig Butz)

---

---

---

---

---

---

---

---



Ivanpah Solar Power Facility generating power on April 29, 2013 (Aioannides)

---

---

---

---

---

---

---

---