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Power Plants and Distribution

How we get our electricity

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Importance and Composition of Electricity

- About 40% of our energy consumption is carried out at electrical power plants
- Sources are diversified (2011 figures):
  - 46% coal
  - 21% nuclear
  - 20% natural gas (growing most rapidly)
  - 8% hydroelectric (3% of the *input* is hydro: it's efficient)
  - 3% wind
  - 1% biomass
  - 0.8% petroleum
  - 0.5% other (geothermal, solar in 9:1 ratio)

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Common Themes

- 99.9% of these turn generators to make electricity
  - all but solar photovoltaics
- 97% power generators are turbine-based
  - all but wind, solar PV
- 89% of turbines powered by heat/steam
  - all but hydroelectric, wind, solar PV
  - includes coal, petroleum, gas, nuclear, etc.

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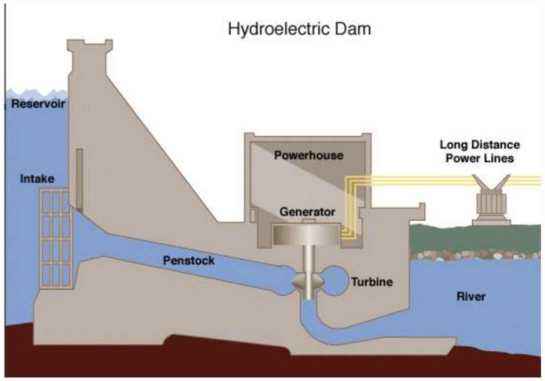
Hydroelectric power



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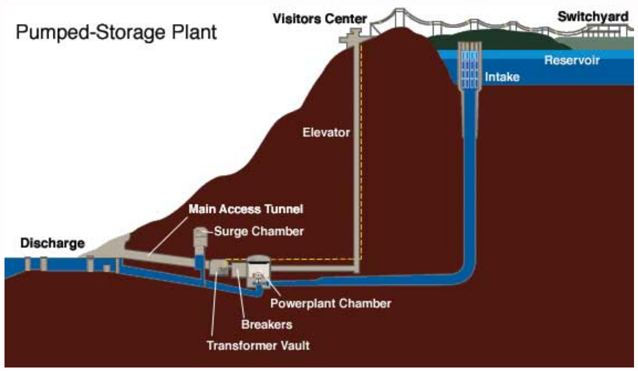
A Hydroelectric "Battery"



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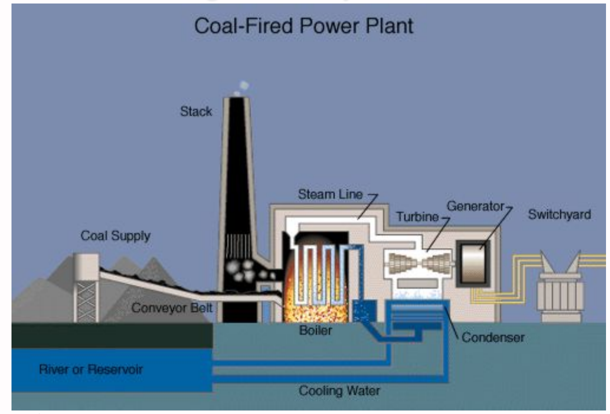
Getting Electricity from Coal



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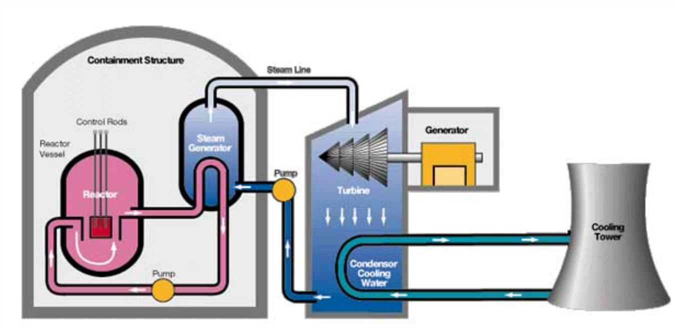
Nuclear Plant



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This covers 97% of our electricity production

- Petroleum and gas plants operate just like coal
- Most use steam in a "heat" engine—the subject of Chapter 3
- All produce electricity through a generator
  - spinning coils of wire within magnetic fields
  - property of electromagnetism that a *changing* magnetic field through a loop of wire produces a voltage along the loop
  - this voltage can drive a current and provide energy to an external circuit

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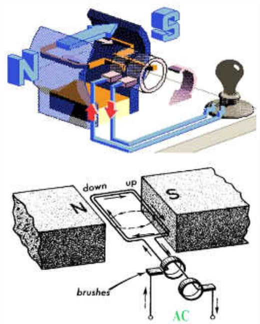
The Generator Principle



- Loop of wire (conductor) rotates within stationary magnetic field
  - this produces *changing* field requirement
- Brush contacts connect to rotating loops and carry current to external circuit
- In practice, wire makes many (thousands of) loops to get a larger voltage
  - each loop adds to voltage
- Simplest arrangement leads to alternating current (AC)

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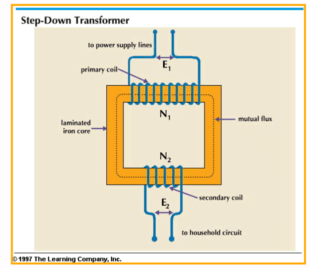
The Transformer Principle



- Transformers use similar principle to step-up or step-down voltage
- Current through loop produces magnetic field along axis of loop
- Alternating current produces *changing* magnetic field
- Magnetic field carried along iron core
- Secondary coil sees changing magnetic field and develops alternating voltage
- Ratio of voltages is just ratio of turns in the two coils: $V_2 = (N_2/N_1)\, V_1$
- Allows transmission at high voltage, household at low voltage

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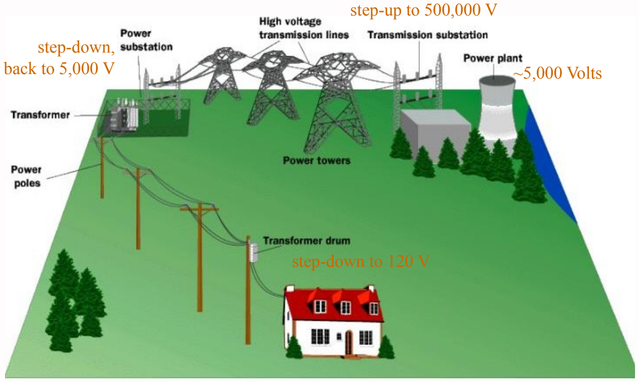
A way to provide high efficiency, safe low voltage:

step-up to 500,000 V

step-down, back to 5,000 V

~5,000 Volts



step-down to 120 V

High Voltage Transmission Lines
Low Voltage to Consumers

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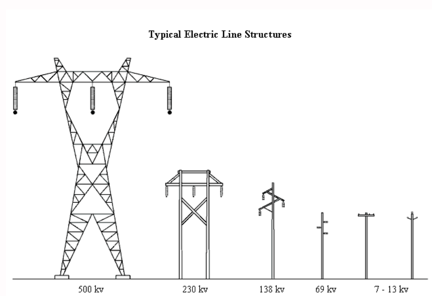
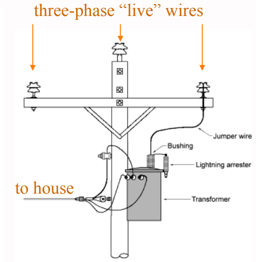
Transmission structures

three-phase "live" wires





to house

500,000 230,000 138,000 69,000 7–13,000
long-distance ⟶ neighborhood

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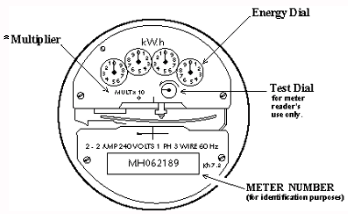
Measuring your electricity consumption

- All houses/apartments have energy meters to monitor electricity usage
  - this is what the bill is based on
- Dials accumulate kWh of usage
- Disk turns at rate proportional to power consumption
  - Kh value is the number of Watt-hours per turn (1 Wh = 3600 J)
- Example: one turn in 10 sec

  (7.2 Wh)×(3600 J/Wh)/(10 sec) = 2592 J/s = 2.6 kW
- Takes 138.9 turns for 1 kWh
- Digital meters have simulated disk
  - 1 Wh per block appear/disappear



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Example data from energy meter, pre-reduction

- Assessed in 2006, before reduction campaign
- During the day at my house, the dial took about 3 minutes to make a revolution.
  - one revolution is 7.2 Wh = 7.2×3600 = 25,920 J
  - 180 seconds per revolution means about 144 W
    - computer, clocks, VCR, etc.
- Average usage was 16 kWh per day:
  - 24 hours in day means average rate of 667 W
  - For 2 people→333 W each: 1/30th of our 10kW share
  - means most of energy not used at home: industry and transportation are the big consumers on our behalves

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References & Assignments

- HW 3 due Friday
- Quiz 3 will be available Thursday afternoon
- Will set up Extra Credit involving reading and interpreting electrical utility meter; stay tuned
- Midterm approaching; May 6
  - will make study guide available, and hold review session

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