Lecture 13: Energy

Energy For Canada

Three Types of Energy

- We use three main types of energy:

Nuclear
- Nuclei decay, split, or fuse
- We use a nuclear reactor to produce heat and steam for electricity generation
- Radioactive decay heats the earths core
- Fusion of light nuclei in the sun produce light

Chemical
- Breaking chemical bonds
- Redox reactions in a battery
- Ex. burning gasoline in a car

Thermo-mechanical
- Potential energy - ex. water stored behind a hydro dam
- Kinetic energy - ex. when water falling or air moving

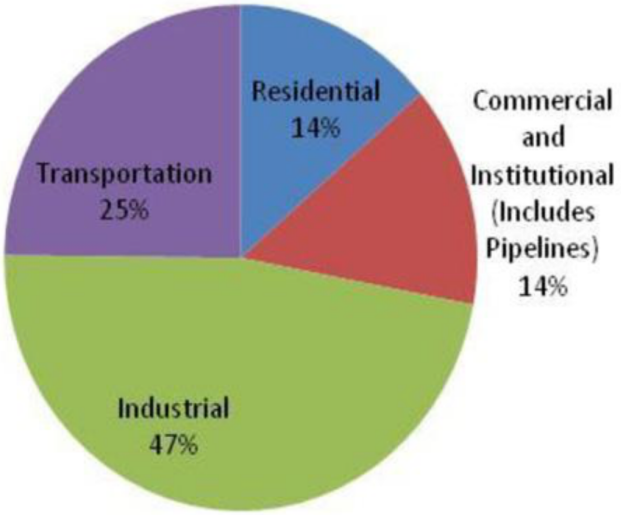
How Much Energy Does Each Person Use?

- Annual per capita usage of energy in the USA in 2013 was equal to 3500 kg of petroleum, 3700 kg of coal, or 3850 kg of natural gas
- The products we use on a regular basis require energy to produce as well
- A large portion of the energy used per capita is used on industrial and commercial uses
- We are the “indirect” users

Common Units for Measuring Energy

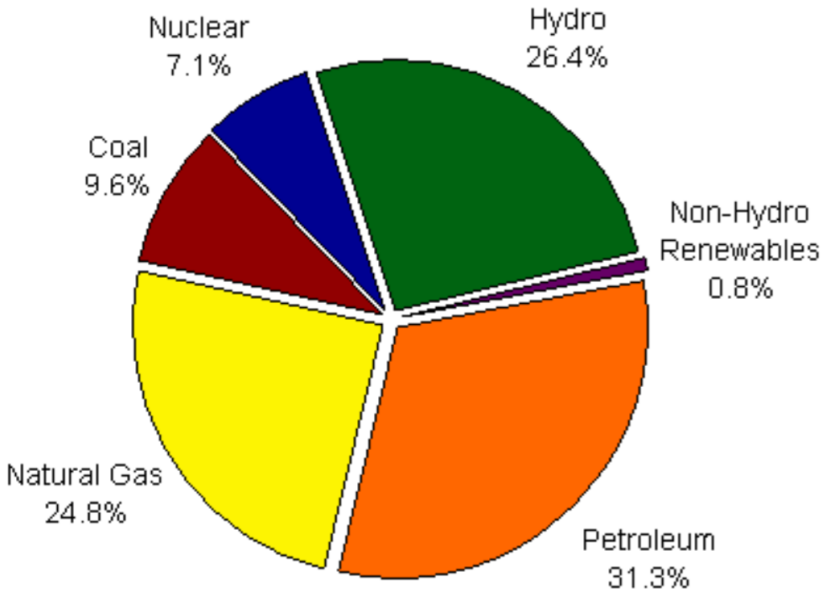
- 1 calorie = the energy required to heat 1 gram of water by 1 C
- 1 joule = the energy required to accelerate 1 kg to 1 m/s^2
- Power = energy/time
- 1 Watt of electricity = 1 J/s
- 1 kWh = 3.6×10^6 Joules
- 1 barrel of oil = 159 L = 6.12 GJ (Giga Joules, 10^9)

Energy Consumption



- Industrial uses the most, at 47%
- Transportation uses 25%
- Residential uses 14%
- Commercial and institutional uses 14%
- Generally, the higher prosperity of a country (per capita GDP), the more energy the country uses
- Most of the energy is consumed by making things
- Colder countries typically use more energy as well
- Canada is really big, so energy is lost in long distance transmission lines
- Goods also have to be transported farther
- Are resources are also energy intensive (smelting ores uses a lot of energy)

Canada's Energy Sources

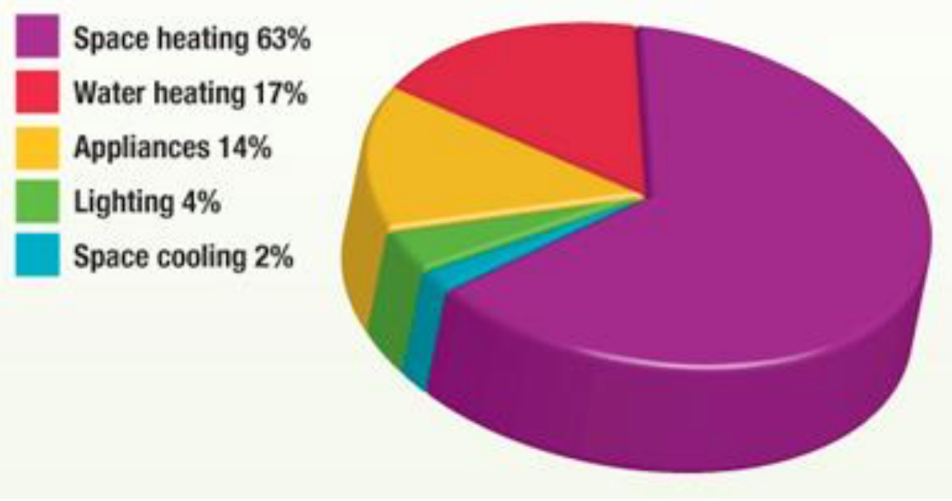


(2008 statistics)

- Petroleum = 31%
- Hydro = 26%
- Natural gas = 25%
- Coal = 10%
- Nuclear = 7%
- Non-hydro renewables (ex. solar) = 1%

Canadian Homes Energy Use

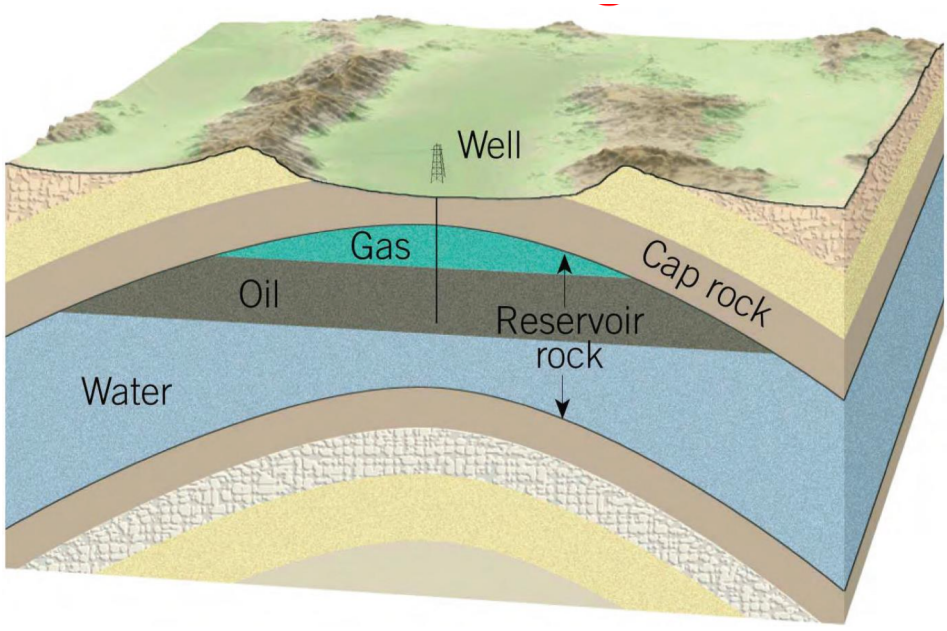
- Space heating = 63%
- Water heating = 17%
- Appliances = 14%
- Lighting = 4%
- Space cooling = 2%



Oil and Gas

- Most of the oil and gas deposits occur in sedimentary rock
- They do not occur in igneous or metamorphic rocks
- The oil deposits are made from very rich terrestrial or marine supplies of organic material that deposits quickly in the sediment
- Since the organic material is deposited quickly, it does not have time to decompose
- Most deposits we are accessing today are hundreds of millions of years old
- The material migrates from the source rock
- A cap rock will prevent it from moving any further
- The material separates out from density and miscibility
- Gas is lighter than oil and water, so it sits on the top
- Oil is lighter than water so it sits in between the gas and the water
- We drill down into the rock, and if there is a positive pressure, the oil and gas will flow up
- If there is not a positive pressure, we will use suction to extract it

- Oil deposits can be found in Ontario and Alberta, as well as off shore of Newfoundland and Nova Scotia (deposits in Ontario are small relative to the ones in Alberta
- The oil deposits near Newfoundland and nova scotia are hard to find and access, and dangerous to mine because they are underwater
- Gasoline offers ~46 MJ/kg
- It is typically use in automotive engines
- It is a chemical source of energy
- Petroleum products are very easy to transport
- Uranium-235 is a nuclear fission energy type, and provides 83 140 000 MJ/kg
- U-235 is most commonly used in electric power plants (nuclear reactors)



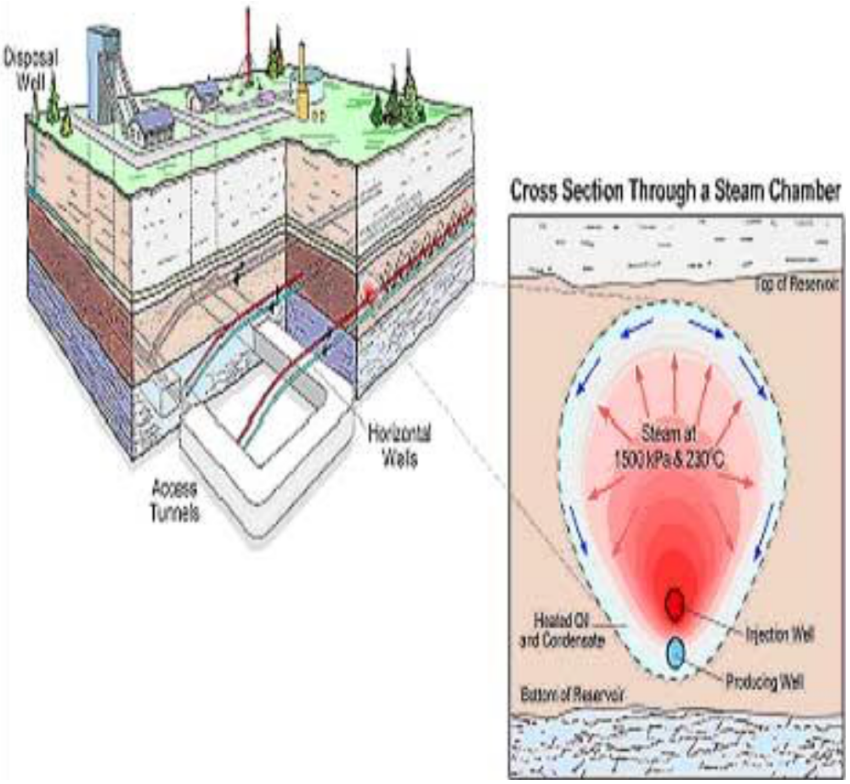
- A big challenge is finding these deposits

Alternatives to Oil and Coal

- Some of the alternatives to oil and coal are;
  - Improving efficiency
  - Unconventional oil and gas
  - Biomass
  - Hydroelectric
  - Tides and waves
  - Nuclear
  - Fusion
  - Hydrogen
  - Solar
  - Wind

Improving efficiency

- By improving efficiency, we can save about 15% (15% of what?)
- In a kettle, about 70% of the energy goes into the surroundings, instead of the water
- Double-paned windows with argon in between
- Argon is a fairly good thermal insulator



Unconventional oil and gas

- Unconventional refers to how you get it out of the ground

Bitumen
- A mixture of hydrocarbons ranging from CH_4 to long chained polymers
- We heat the sand and get the hydrocarbons flow out
- Bitumen is too viscous to flow unless heated or decomposed
- We pump heat in through the injection well, and it diffuses throughout the cavity
- By adding heat, the bitumen will flow
- We then pump it out of the “producing well”
- We use steam as our source of heat
- Canada is a net exporter of oil (we export more than we import)

Pros:
- It is found in the Alberta (oil sands)
- Ex. mining and refining oil “tar” sands
- There are huge oil sand reserves in Canada, as well as internationally
- They have a known distribution, making exploration easier
- Mining it in Canada reduces shipping costs, as well as giving international independence for Canada and the USA
- Saudi Arabia produces 260b barrels of oil, Venezuela 211b, Alberta 171b, Iran 137b, etc.

Cons:
- Mining the oil sands requires large amounts of energy (>10% of the amount extracted goes to mining the shit)
- Requires 28 m^3 of natural gas and 2.5 - 4 barrels of water for 1 barrel of bitumen
- Refining bitumen is more complex and more expensive
- Potential to contaminate land and water surrounding mining areas
- Produces lots of carbon emission, as well as waste (from sand and water)

Shale fracking
- We can frack shale gases to get gas and oil
- When fracking shale gas, we are extracting a gaseous material
- The gas is stuck in the shale and we must figure out how to get it out
- If you were to drill into the shale, you would not get anything out because the drill hole is not connected to the deposit?***
- To extract the shale gas, small explosions are detonated underground and a solution of very fine sand grains and water is pushed into the fractures to hold them open
- Essentially we are using explosions to open up the pores in the rock and extract the gas
- Fracking techniques are being rapidly developed in the USA to take advantage of the shale gas/oil sources
- There is a growing concern that fracking can lead to unstable rock formations that may lead to earthquakes

Pros:
- Shale fracking enhances recovery of gas and oil
- There are large reserves in Canada and the USA
- Having it domestically available reduces shipping costs and international dependence
- Shale is making the USA self sufficient in oil & gas consumption

Cons:

- It requires water/steam, sand, and chemicals to open up the deposit so gas/oil will flow to wells
- Drilling is more expensive and complex
- Refining is more expensive and complex
- There is a concern that groundwater supplies will be contaminated (we are injecting a bunch of stuff into the ground)
- Their is evidence that fracking may lead to small seismic activity

Biomass

Pros:
- Ex. wood
- Has been used for centuries for heat and cooking
- Biomass resources are widespread - trees and agricultural waste
- High efficiency wood stoves are affordable and widely available

Cons:
- However, the energy per unit of volume is much lower than oil/gas
- Transporting wood large distances is not economical
- As a result, biomass does not scale to industrial processes
- A lot of particulate emissions are released from wood smoke
- Wood smoke is a known carcinogen
- Particulate emissions need to be scrubbed from the air to reduce potential health effects

Hydroelectric

Pros:
- Falling water has been used for centuries
- It is easy to adjust electricity production to changes in demand - you can increase the # of turbines, volume, or flow (open up the passage to another turbine)
- Low carbon emissions, although some methane is emitted from the flooded land

Cons:
- The dams flood large areas and impacts the fish/wildlife movement and habitat
- Most sites close to population centres have already been dammed and are in use
- Volume and flow vary seasonally
- Silt and sediment fill the reservoir behind the dam
  - The sediment is extremely hard to take out

Tide and Wave

Pros:
- Available on coastlines globally
- Small scale systems work like a dam
- Free standing turbines can be put into the middle of a bay (an “open flowing system”)

Cons:
- Dams increase sedimentation and damage habitats
- It is difficult to collect the widely distributed energy

- Needs large tides and consistent waves to be efficient and economical
- Waves vary with wind, and tides only “flow” twice a day
- No one has made an “open flowing system” that actually works

Nuclear

Pros:
- It is a proven technology (Ontario’s power is about 50% and France 100% nuclear)
- No green house gas emissions
- Fuel is inexpensive and abundant
- Good for feeding electric grid
- Small volumes of waste produced vs. other combustibles

Cons:
- Public link nuclear energy to war and nuclear weapons
- Plutonium and uranium can be used to make weapons
- Reactors are very expensive to build
- Public concern about nuclear waste storage
- Perception that it is more complex and dangerous

Solar

Pros:
- Two choices (heat, and photoelectric)
- Renewable
- Widespread
- Passive heating is simple for small systems

Cons:
- Not available 24/7 (night, clouds, etc.)
- Need a large collection area
- Currently is expensive to manufacture solar cells
- We need better storage and conversion technologies
- Insolation depends on latitude (sun’s angle, day length) and cloud cover
- Canada has short days in the winter

Wind

Pros:
- Renewable
- Widespread
- Can use existing hydro grid infrastructure
- Available where other renewables are not found (ex. arctic regions)

Cons:
- Inconsistent supply
- Visual clutter
- Noisy

- Energy output depends strongly on wind velocity (we ned at least 15 - 20 km/h wind speeds for it to be economical. Wind speeds this fast are not possible at many sites in Canada)
- In the equation for energy output, wind velocity is a cubed function

Renewable Energy in Canada

- Large hydroelectric = 86%
- Biomass = 6%
- Small hydroelectric = 4%
- Wind = 3%
- Biogas = 1%

Energy in the World

- 81% of the world uses fossil fuels
- 17% use renewables
- 3% use nuclear

- The largest source of renewables is biomass heat, making up 11.4% of the whole 17%
- Hydropower is next, making up 3.3%

Summary

- Canadians use lot of energy - we have a cold climate, big country, and high GDP
- Energy units are different for different sources (electricity in MW, oil in barrels, etc.)
- Oil and gas are the dominant sources of energy
- Large supplies of unconventional oil & gas are in North America
- Renewables are growing rapidly
- Efficiency is key for all energy sources and uses
- The world and Canada use a mixture of energy sources
- The world needs to continue innovation of our technologies