Ch. W20: Conventional energy alternatives

You may notice that the Withgott 7e text divides energy into three main categories:

- Chapter 19: Fossil fuels
- Chapter 20: Conventional energy alternatives (nuclear, biofuels, hydropower)
- Chapter 21: Emerging renewable energy (solar, wind, geothermal, ocean, hydrogen storage)

Bozeman Science:

025 - Nuclear Energy

http://www.bozemanscience.com/ap-es-025-nuclear-energy

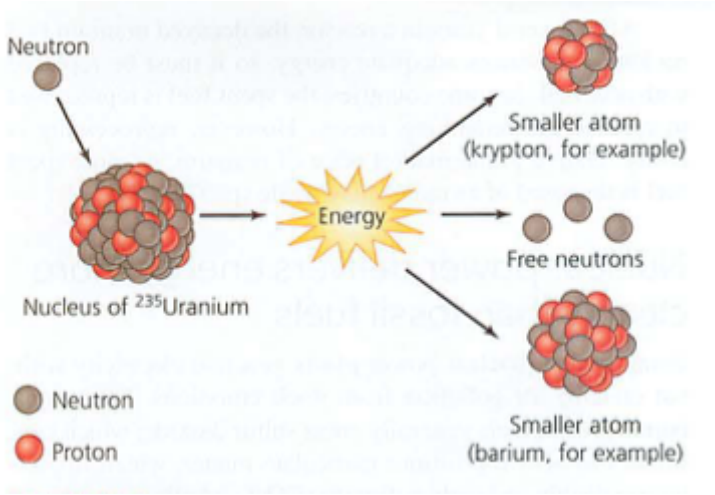
026 - Hydroelectric Power

http://www.bozemanscience.com/ap-es-026-hydroelectric-power

This makes a great deal of sense, so below you will find notes from Chapter 20 (I may add notes from 19 later)

Chapter 20: Conventional energy alternatives (nuclear, biofuels, hydropower)
n.b. the text seems to refer to energy policies in Sweden quite a bit: why do you think?

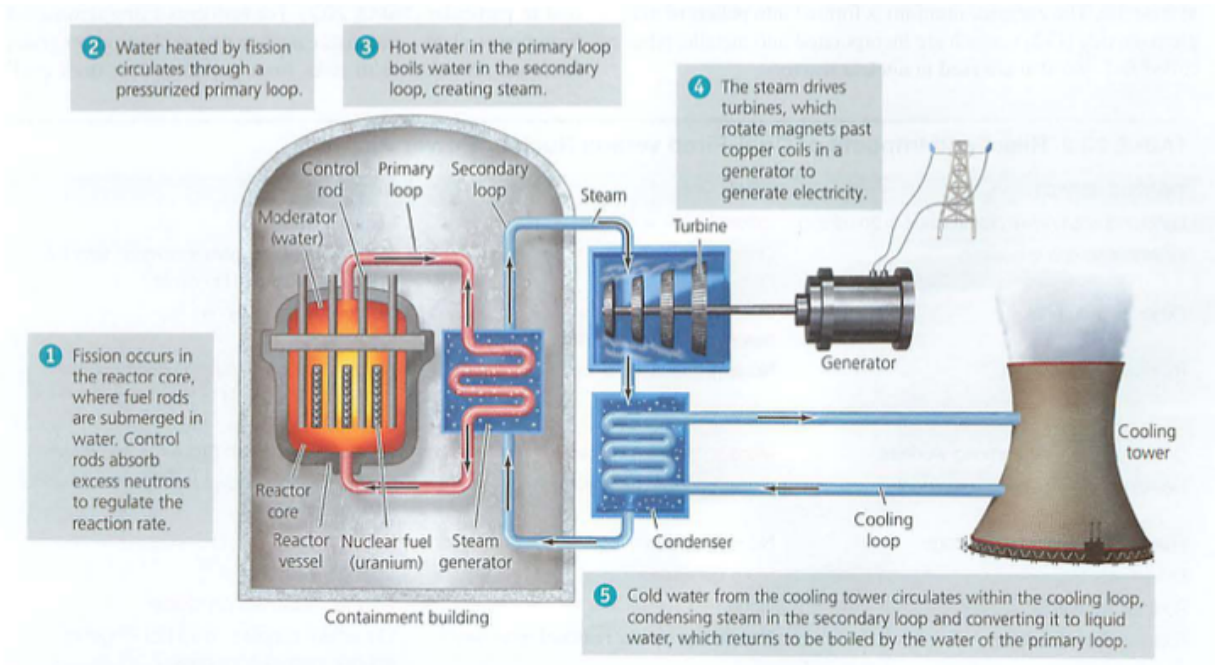
Part I: Nuclear Power:
Fission for now:



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Make sure to understand the difference between U238 (common) and U235 (rare, must be refined to get, known as "enriched Uranium")
You may also hear about "enriched Uranium in the news about countries like Iran and N. Korea, where enriched Uranium can be used for nuclear weapons, as well as fuel for energy reactors

Make sure you understand each of these elements, but more, how are they similar and different from a coal fired power plant?



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Realize also that this is called a Pressurized light Water Reactor (PWR) which is the most common. Make sure to look up the other, more dangerous type, called the BWR or boiling water reactor. The main difference is this one has a primary loop that is separated from the secondary steam loop.

You may also hear about a PWR "heavy water" reactor, which uses depleted fuels to create Plutonium for weapons...
Good to know for the AP exam:

TABLE 20.1 **Top Producers of Nuclear Power**

NATION	NUCLEAR POWER CAPACITY (gigawatts)	NUMBER OF REACTORS	ELECTRICITY FROM NUCLEAR POWER (%)
United States	100.0	99	20.0
France	63.1	58	71.6
Japan	39.8	42	3.6
China	34.5	39	3.9
Russia	26.1	35	17.8
South Korea	23.1	25	27.1
Canada	13.6	19	14.6
Ukraine	13.1	15	55.1
Germany	10.8	8	11.6
Sweden	9.1	9	39.6

Data from International Atomic Energy Agency.

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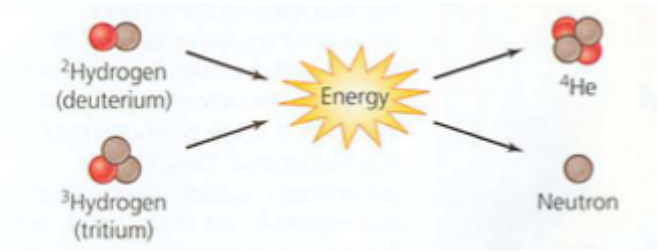
You should also know the term "mill tailings" which are radioactive and toxic leftovers from mining and refining Uranium.
From your e2 video "coal vs. nuclear" you should be able to list a few of these:

TABLE 20.2 **Risks and Impacts of Coal-Fired versus Nuclear Power Plants**

TYPE OF IMPACT	COAL	NUCLEAR
Land and ecosystem disturbance from mining	Extensive, on surface or underground	Less extensive
Greenhouse gas emissions	Considerable emissions	None from plant operation; much less than coal over the entire life-cycle
Other air pollutants	Sulfur dioxide, nitrogen oxides, particulate matter, and other pollutants	No pollutant emissions
Radioactive emissions	No appreciable emissions	No appreciable emissions during normal operation; possibility of emissions during severe accident
Occupational health among workers	More known health problems and fatalities	Fewer known health problems and fatalities
Health impacts on nearby residents	Air pollution impairs health	No appreciable known health impacts under normal operation
Effects of accident or sabotage	No widespread effects	Potentially catastrophic widespread effects
Solid waste	More generated	Less generated
Radioactive waste	None	Radioactive waste generated
Fuel supplies remaining	Should last several hundred more years	Uncertain; supplies could last longer or shorter than coal supplies

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The text refers to Fusion as a "dream" but you know that recently (January 2023) Fusion achieved "break even" meaning it had an EROEI of 1:1 for the first time EVER. They've been working on this since 1950, so this is a very big deal.
Here's the reaction:



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Three main accidents covered in the text:

Three Mile Island: Pennsylvania, 1979

- partial meltdown
- still toxic
- some radioactive gas released
- no stats on health impact or death
- caused by human error

Chernobyl: Ukraine (was USSR), 1986

- human error
- bad design
- poor response
- some killed directly
- many millions impacted, early cancers (thyroid, others)
- 100+ tons of radioactive material released
- still toxic for 20 miles around
- top 2m of topsoil was removed, buried deep underground

Fukushima: Japan, 2011

- tsunami, flooded electrical generators
- full meltdown 3x, partial another 3x
- still very radioactive, releasing radioactive water into the sea

Next big issue: nuclear waste:

- dangerous to store
- dangerous to move to storage sites
- can be used for "dirty bombs" (conventional explosives + radioactive waste)
- melts containers, can get into ground water
- radioactive for thousands of years

Reactor design:

Gen 1 reactors: Submarines, early shore reactors
Gen 2 reactors: most present reactors
Gen 3 reactors: better recent design, some using heat convection like the SMR modular reactor
Gen 4 reactors: pebble bed reactor, liquid sodium reactor, molten salt reactor

Part II: Bioenergy

Basically anything that was living, used as fuel for energy

Examples:

TABLE 20.3 Sources and Uses of Bioenergy

DIRECT COMBUSTION FOR HEATING

- Wood cut from trees (fuelwood)
- Charcoal
- Manure from farm animals

BIOPOWER FOR GENERATING ELECTRICITY

- Crop residues (such as cornstalks) burned at power plants
- Forestry residues (wood waste from logging) burned at power plants
- Processing wastes (solid or liquid waste from sawmills, pulp mills, and paper mills) burned at power plants
- "Landfill gas" burned at power plants
- Livestock waste from feedlots for gas from anaerobic digesters

BIOFUELS FOR POWERING VEHICLES

- Corn grown for ethanol
- Bagasse (sugarcane residue) grown for ethanol
- Soybeans, rapeseed, and other crops grown for biodiesel
- Used cooking oil for biodiesel
- Plant matter treated with enzymes to produce cellulosic ethanol
- Algae grown for biofuels

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Issues:

- Diversion of food
- Impact on erosion, soil health, nutrients
- EROEI less than 1.0 for corn ethanol in the US (very political)

Main versions:

1. Direct burning: wood, manure, bagasse
2. Fermentation: corn, sugar cane or other sugar crop grown, fermented to make ethanol (alcohol)
3. Cellulosic ethanol: using non-food crops (waste, grasses) with bacteria and yeast to create ethanol
4. Biodiesel: from oily crops (rapeseed)
5. Algal biodiesel: from algae

EROEI (energy return on energy invested)

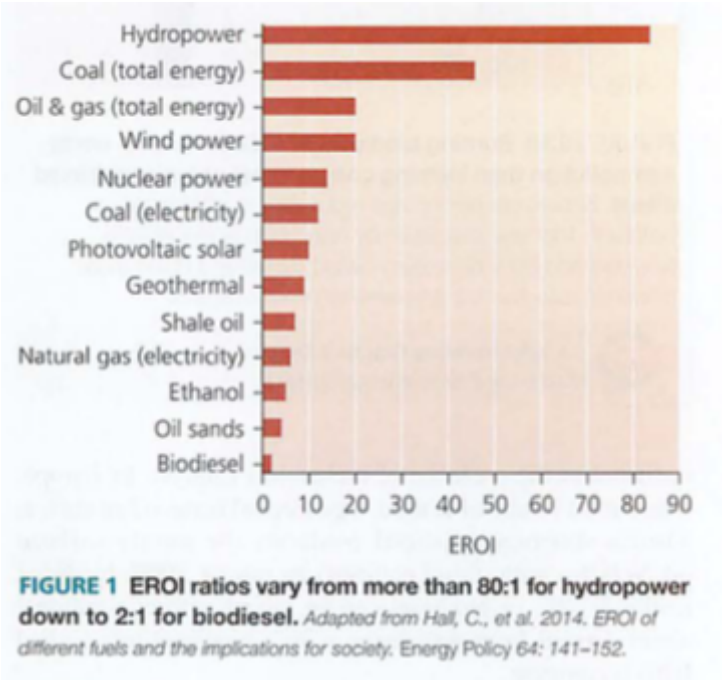


FIGURE 1 EROI ratios vary from more than 80:1 for hydropower down to 2:1 for biodiesel. *Adapted from Hall, C., et al. 2014. EROI of different fuels and the implications for society. Energy Policy 64: 141–152.*

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Note that EROEI for ethanol depends on where it is grown: corn (US) vs. sugarcane (Brazil)

Part III: Hydropower
Three main topics:
1. Hydroelectric dams (PE of water behind dam becomes KE of water through turbine)
2. Run of the river hydropower (KE of water flowing through turbines, no dam)
3. PSH: pumped storage hydro (essentially creating a dam or pond as hydropower storage)

- Very high EROEI (80:1)
- Finite lifespan for dams
- Dams impact downstream life as well as upstream dislocation
- Only available where there is consistent flow of water, and location for dam
- Different from tidal or ocean energy, as all dams are freshwater

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