ENE3048 Energy and the Environment

Exam Study Guide

Week 1

Energy

- cannot be created or destroyed
- can be transformed
- different forms: mechanical, sound, chemical, electrical, light, heat, nuclear
- key issue is to get it into a useful form, at the right place and time, as efficiently as possible

Force (N)- causes a change in motion of an object

Work (J or N/s or Nm)- the exertion of a force over a distance- force x distance

Energy (J)- the potential to do work (is expended when work is done)

Power (W or J/s)- the rate at which energy is used

Types of Energy

1. Kinetic Energy - associated with the movement of an object, can be translational or rotational
2. Potential Energy- associated with the energy of an object in a gravitational field -> position
3. Thermal Energy- kinetic energy associated with the microscopic movement of molecules
4. Chemical Energy- associated with chemical bonds, released in exothermic or absorbed in
1. endothermic reactions
5. Electrical Energy- associated with the flow of electrons in a conductor
6. Electromagnetic Energy- energy of the electric and magnetic fields associated with
2. electromagnetic waves (photons)
7. Nuclear Energy- associated with the bonds between neutrons and protons in the nucleus
8. Sound- associated with the vibration of matter

Note: Mechanical Energy is the sum of Kinetic, Potential and Rotational Energy!

Kinetic Energy

$$E = \frac{1}{2}mv^2$$

– or rotational motion (or both)

$$E = \frac{1}{2}I\omega^2$$

Thermal Energy (gas)

$$E = \frac{3}{2}nRT$$

Thermal energy (liquids and solids)

A quantity of energy Q supplied to a material of mass m and specific heat C will increase the temperature by ΔT

$$\Delta T = \frac{Q}{mC} \qquad (1.12)$$

Electrical Energy

- current I flowing through a conductor with a resistance R will experience a voltage drop V given by Ohm's law

$$V = IR \qquad (1$$

Power dissipated through the resistance is

$$P = VI \qquad (1.$$

Nuclear Energy

- greater than chemical energy, may be released during nuclear reactions

- energy release during an exothermic nuclear reaction is related to changes in the total mass of the system by Einstein's relation

$$E_{exo} = \Delta mc^2 \qquad (1.21)$$

Chemical Energy: Energy released in combustion (burning) is the heat of combustion

Calorific energy content- the material that can be converted to electrical energy in three energy conversion processes (in that order)

- the amount of energy that can be extracted from a material!

1. Combustion/ heat energy
2. Kinetic energy (turbine)
3. Generation (generator)

- each conversion step introduces inefficiencies

Thermodynamic Laws

1. Zeroth Law: If two systems are in thermal equilibrium with a third, then they are in thermal equilibrium with each other
2. First Law: The change in internal energy of a closed system is equal to the heat added to the system (or absorbed from the environment) minus the work done by the system (or on the environment)
3. Second Law: The entropy of an isolated system not in equilibrium will tend to increase over time, approaching a maximum value at equilibrium

How Humans use Energy: 18% Efficient

Global average annual energy footprint per person: 20 MWh (95 MWh in the US)

- worlds energy usage is becoming more efficient, but still increasing as populations grow and we find more and more things to use energy for
- greater use of renewable energy, but non-renewables are also still being built to meet increasing population energy demands

Sankey diagram- shows energy sources, uses and losses

Electric power plant efficiency (η)- the ratio between the useful electricity output from the generating unit and the energy value of the energy source supplied, in a specific time

- large scale hydro electric energy generation is the most efficient of all

—> Efficiency = useful energy output / energy input

Electricity

Electricity- driven by electromagnetic force of atoms, results from electrons moving across atoms

- the flow of electrons, when an electron jumps from the orbit of one atom's nucleus into another
- every atom is made up of a nucleus surrounded by orbiting electrons, which are tiny charged particles

Electricity is made in 2 ways

1. Solar Panels

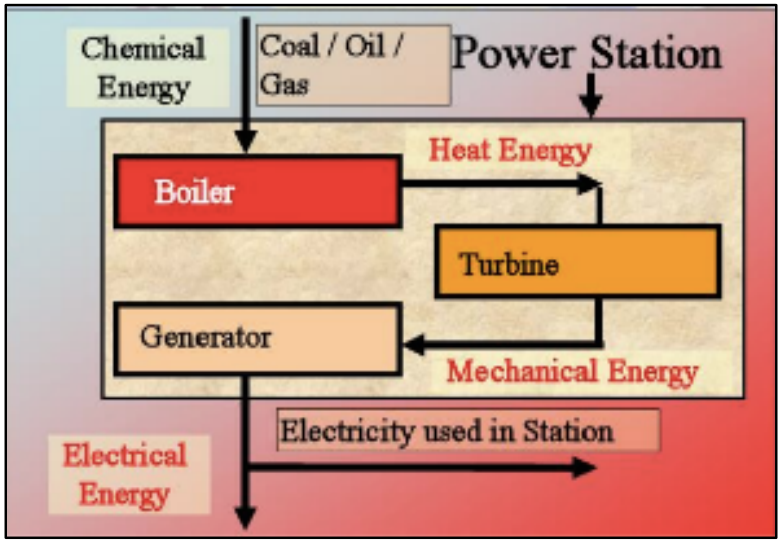
- solar panels turn light into electricity using silicon, providing 1% of global electricity

2. Generators

- 99% of electricity comes from turning generators
- Generator: magnets surrounding a core of coiled wire, the coil turns within the generator to make electricity (different sources to make the coil turn)

- most power plants use a heat source: coal, natural gas, nuclear, oil, biomass or geothermal
- that heat boils water to make steam, which turns a turbine connected to a generator
- in dams, water turns a turbine which turns the generator
- with wind power, wind turns the turbine
- historically, electricity infrastructure was planned, owned and managed by a single 'utility'
- today electricity networks are divided into: generation, transmission, distribution, retailing,
- ancillary services

Conventional Electricity Power Station



Power Plant capacity factor (actual output/ potential output)

$$Capacity\ Factor = \frac{average\ power}{max\ power\ capability} = \frac{actual\ output\ over\ a\ period\ of\ time}{potential\ output\ for\ continuous\ operation\ in\ same\ period\ at\ full\ nameplate\ capacity}$$

—> Ratio of: The actual power output in a specific time period / The maximum potential output at full capacity and continuous operation over the same time period

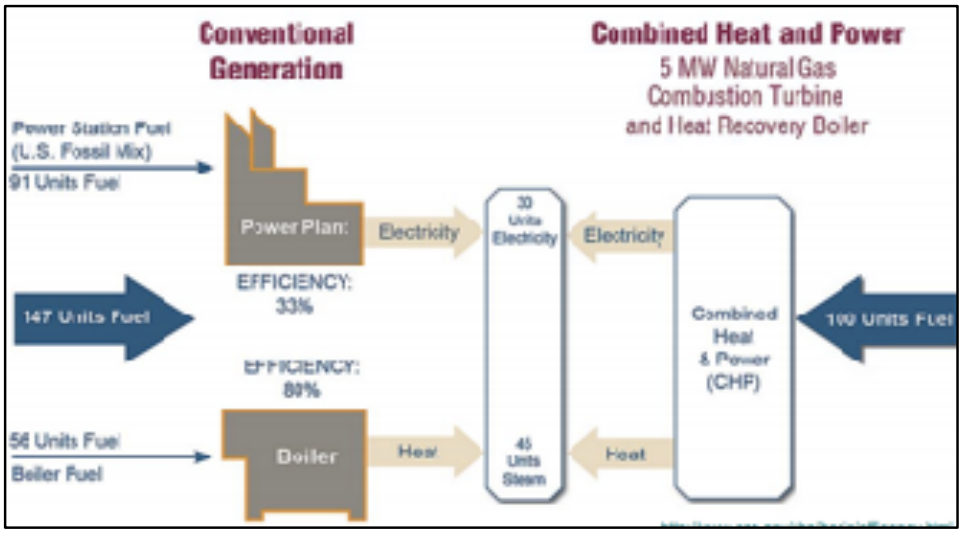
- non-renewables have a higher capacity factor (used to their potential), especially uranium
- renewables often have intermitted supplies
- maintenance times for both renewable and non-renewable
- out of renewables, hydro has the highest capacity factor

Death by capacity factor

- only 2 units of light energy from lamp generated for every 100 units of coal input -> inefficient, high energy losses
- natural gas is more efficient

Efficiencies:
- Coal: 27% - 43% ~35%
- Natural Gas: 31% - 55% ~45%

- combined heat and power plant (CHP) is more efficient than conventional plants (separate heat and power) - 75% vs 51% overall efficiency
- Co-generation



Electricity Market
- electricity cannot be stored on a large scale
- when an electrical appliance is switched on, power is instantly transmitted from a power station to the appliance
- electricity market works as a “pool”, or spot market
- power supply and demand is matched instantaneously
- real time via centrally coordinated dispatch processes

Transport of electricity: converted to high voltage for efficient transport, then re-converted to low voltage for distribution