GEC1010
AY22/23 Sem 2
github.com/securespider

01. Energy

By constant force

work done by a force == force * displacement
$W = FS$

Law of conservation of energy

Energy can neither be created nor destroyed, it can only be transformed from one form to another

Kinetic energy

linear motion - $K = \frac{1}{2}mv^2$

angular motion - $\frac{1}{2}I\omega^2$

- I = Moment of inertia of object (dependent on mass distribution of object)
- ω = angular velocity of the rotating object
  - Rad/second
  - $v = \omega * radius$

Gravitational potential energy

$U = mgh$

Power

Rate of doing work or rate of consumption of energy
$P = \frac{\triangle W}{\triangle t}$
Work done, W, by a system in time t

Requirements of an energy system

Energy resource

- Clean energy
  - Wind Energy
  - **Hydro energy** - Come from river and dams
  - Ocean energyOnly refers to energy coming from ocean currents etc
  - Solar energy
  - Biomass
  - Non-Renewables:
  - Geothermal
  - Nuclear
- Fossil fuels
  - Coal
    * Greater carbon content and more impurities - More carbon dioxide and greater air pollution
    * Solid so difficulty in extraction, transportation and use
  - Natural Gas
    * Cleaner alternative
  - Oil

Problems

- Unsustainable - reserves depleting
- Global warming - Enhanced greenhouse effect by earth atmosphere
- Greater absorption of long wavelength IR in earth's atmosphere
- Rising temperature anomaly from 1980-2000
- Global sea level rising
  - Thermal expansion of water
  - Melting alpine glaciers and ice sheets
- Earlier timing of spring events
- Poleward and upward shift in plant and animal species

Solution:
Clean energy

- Replace existing supply of fossil fuels
- Use energy more efficiently and judiciously minimizing environmental pollution

High power

High energy conversion efficiency

Singapore

Singapore uses LNG primarily (95%) piped from indonesia and malaysia
Switching to solar and biofuels to reduce reliance

Energy conservation

- Outdoor LED initative
- Electric car sharing

02. Fundamentals of thermal energy

$Q = mc\triangle T$

Q Heat energy supplied

m mass

c Specific heat capacity of material

T temperature change resulting from heat energy

$Q = mL$

Q Heat energy supplied

m mass

L Specific latent heat of vaporization/fusion

Types

- Conduction
  - Dominant in solids
  - No bulk motion of matter
  - Heat flows from region of high temperature to region of low temperature
- Convection
  - Dominant in fluids (liquid and gases)
  - Works by circulating fluids and thermal expansion properties of materials
  - Cold fluids sink, warm fluid rise
- Radiation

Stefan Boltzmann Law

Power of black body radiation
$P = \epsilon\sigma T_0^4$

P Energy absorbed per unit second per unit area via radiation

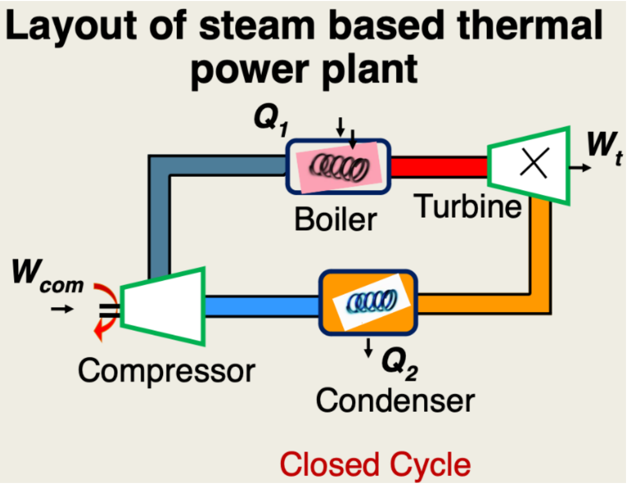
ϵ Emissivity of surface(lies between 0-1)

σ $5.67 * 10^{-8}$ = Stefan Boltzmann constant

First law of thermodynamics

Difference between the heat absorbed Q and the work done W on object is equal to change in internal energy of the thermodynamic system
$Q - W = \triangle U$

Steam based thermal power plant



Key stages

Compression Work done on system to compress cold water to high pressure

Boiling Heat added to the system to convert cold water into steam

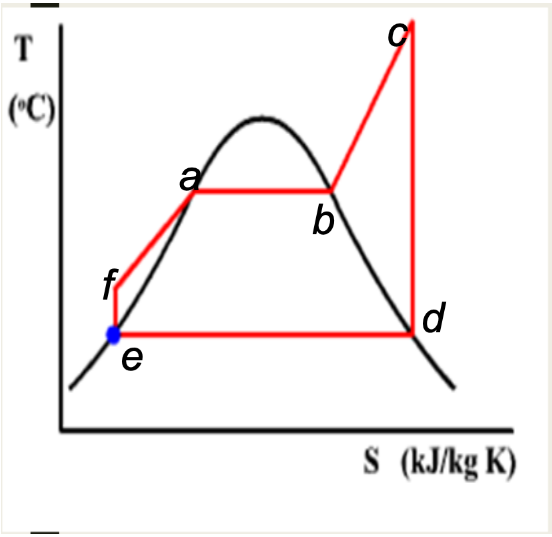
Turbine rotation Work W_t done by the system on turbine blades

Condensation Heat lost from the system to the environment in converting steam back to cold water

- Working fluid have the same amount of energy U as it had in the beginning of the cycle
- Net heat absorbed = $Q_2 - Q_2$

Efficiency of cycle is given by
$\eta = \frac{Net\ output\ work}{heat\ input} = \frac{W_t - W_{com}}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$

Rankine cycle



Steam power plant energy generation (Temperature - entropy graph)

- EF - Compressor increases the pressure of water
- FA - Economiser, Water heated at high pressure until it boils
- AB - Evaporator, 2 phase mixture of water and steam is heated at constant pressure until all water converted to dry steam
- BC - Superheater, Dry steam heated at constant pressure in superheater
- CD - Dry steam enter turbine at high pressure and rotate the turbine
- DE - Steam converted to water
  - Problem: Unable to completely eliminate the formation of water droplets @ CD
  - Solution: Reheat the steam at CD to rotate the turbine again
  - Temperature is raised again, leading to greater efficiency
  - Achieve 40% efficiency
  - Cannot go beyond 650c to prevent metal fatigue

Brayton cycle

Use gas instead of water leading to no worry of water droplets and can go higher temperatures

03. Wind energy

How wind forms

Dominant

- **Coriolis Effect** - Sideward component of wind due to earth rotation
- **Solar radiation** - Warm air rise up in the equator leading to difference in densities

Other factors

- Ocean
  - Water absorbs/releases heat slower than land
  - Day: Water less hot, sea -¿ land
  - Night: Water hotter, land -¿ sea
- Surface friction
- Eddy motion
- Seasonal effects

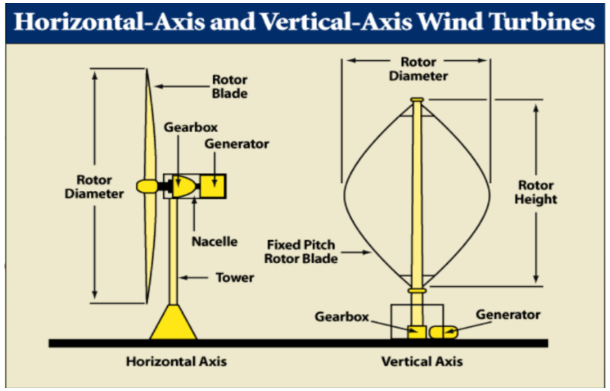
Power of wind

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

Wind speed affected by height of the turbines

- Wind speed rises proportionally to 7th root of altitude

Wind turbines



- **Yaw control** - Orientates the nacelle in direction of incident wind
  - Note: Better for rotor to face the wind
  - Less wind shadowing effect
  - Blades flex less
  - Less fatigue in the blades

Forces

Drag Net force in direction of wind

Lift Net force perpendicular to wind

Blades

Turbines cause turbulence for surrounding blades so cannot have too many blades **Tip Speed Ratio (TSR)** - $\frac{Speed\ of\ rotation\ of\ outer\ tip\ of\ blade}{incident\ wind\ speed}$

Betz limit - Maximum theoretical efficiency of rotor

Capacity factor - $\frac{yield}{rated\ power}$

Dependent on wind speed

Offshore vs Onshore

\+ Wind speed is faster offshore

\+ Less obtrusive

\+ Bigger in size

\+ CF higher

\- Harder to maintain cus in the sea (But easier to build because transportation over water easier)

\- Might spoil faster due to seawater

04a. Solar Power

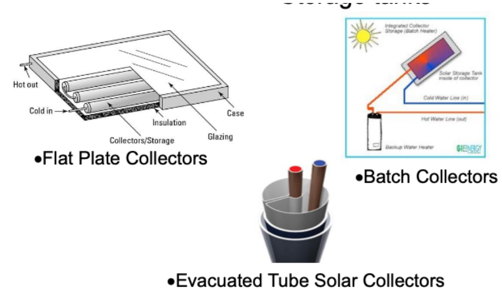
Renewable form of energy with $3.9x10^{26}W$

Only half reach surface of earth

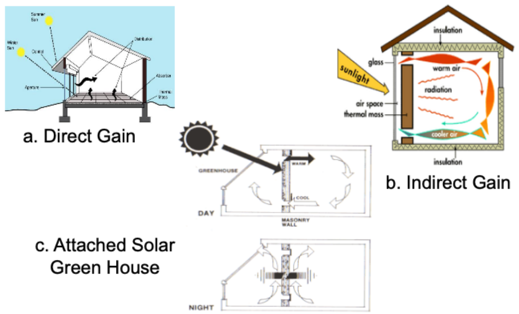
Types of systems

- **Passive** - Uses no external power
  - Allows fluid heated by the sun to circulate by natural means
- **Active** - Solar heated fluid is circulated by a fan or pump

Solar fluid collectors



Passive space heating system



Trombe wall

Principles of passive cooling

- Minimise solar heat gain
  - Increase building mass
  - Increase thermal protection
  - REflective coating on exposed surface
  - shading device
  - Air tightness in building
- Remove unwanted heat
  - Evaporative cooling
  - Nocturnal ventilation
  - Thermo-active ceiling

Solar power energy

Using the heat by the sun to drive rankine cycle

- using mirrors to focus sun light into a tower to heat molten salt
- Run focus pipes surrounded my mirrors to heat the fluid in the pipes to be used to generate heat

Silicon

05. Hydro power

Ocean vs River

River

1. Hydroelectricity

Ocean

1. Tidal power
2. Wave power
3. Ocean thermal

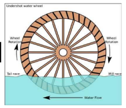
Water wheels

Water mills

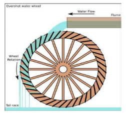
- Ancient application for replacing physical labour
- Replaced with water turbines for energy generation

Types of water wheels

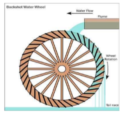
Undershot Water Wheel



Overshot Water Wheel



Backshot Water Wheel



- Undershot
  - Vertically mounted with water flowing at the bottom of the wheel
  - Cheapest and least efficient
- Overshot
  - Falling water on the top of the wheel in direction of rotation
  - Use all water flow for power production
  - Does not require rapid flow of water
  - Uses the difference in weight between the 2 sides of the wheel to turn
- Backshot
  - Introduced behind the apex of the wheel
  - Water flows opposite the direction of rotation
  - Continues to function even when water in wheel put rises beyond height of axle
  - Technique useful for streams that experience extreme seasonal variations in flow

Types of Hydro Power

- Dam based
- Run of the river plants(diversion)
- Pumped storage technology
- Damless hydro power

Principles of power generation

Production of electricity by using gravitational force of falling water

$P = \eta \rho g h Q$

η = efficiency, ρ = density of water, Q = Volume of water flowing per second on turbine, h = Vertical distance between turbine and water surface