能源及環境學院
SCHOOL OF ENERGY AND ENVIRONMENT

香港城市大學
City University of Hong Kong
專業 創新 胸懷全球
Professional · Creative For The World

GE1355
Sustainable Energy and Environmental Engineering

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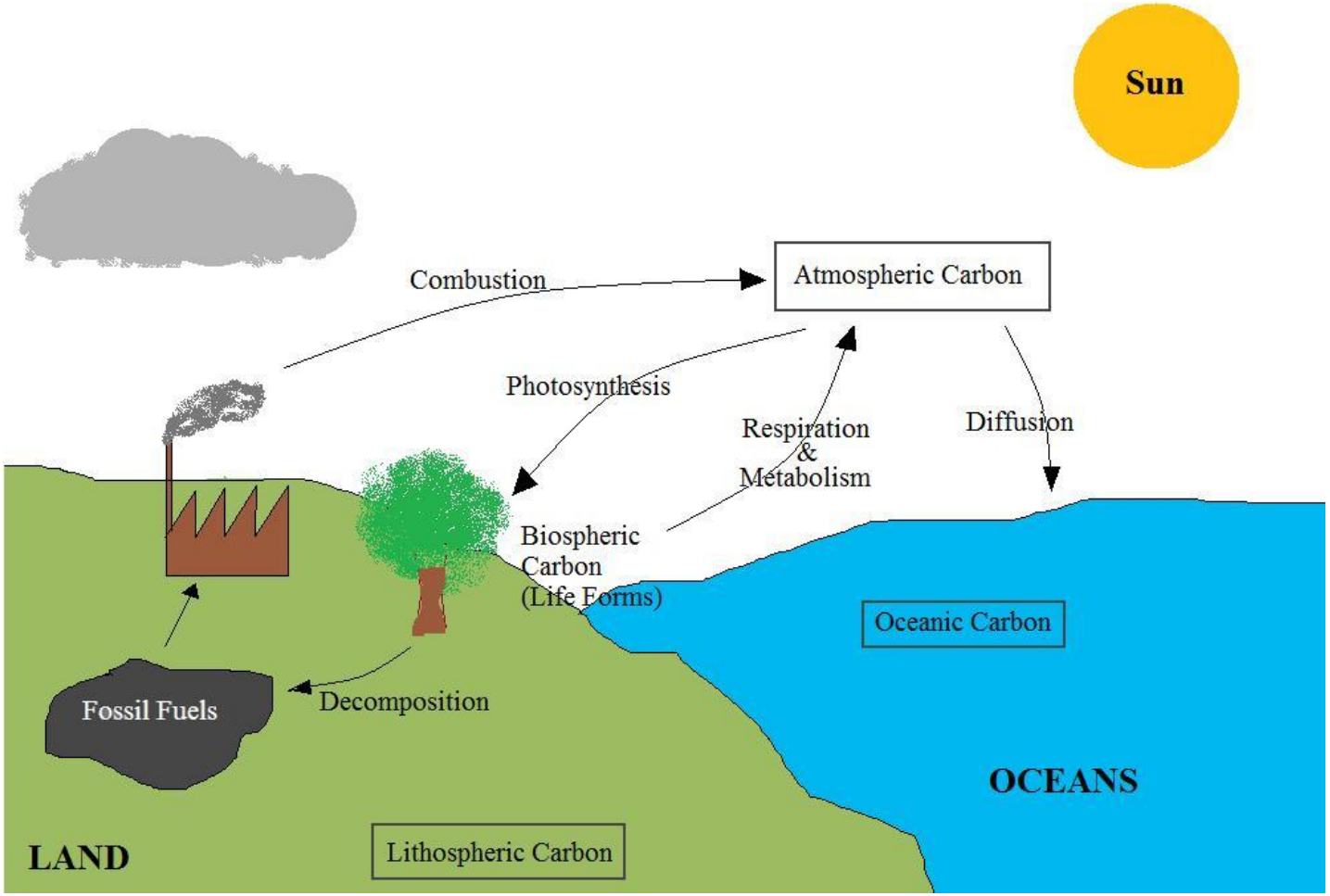
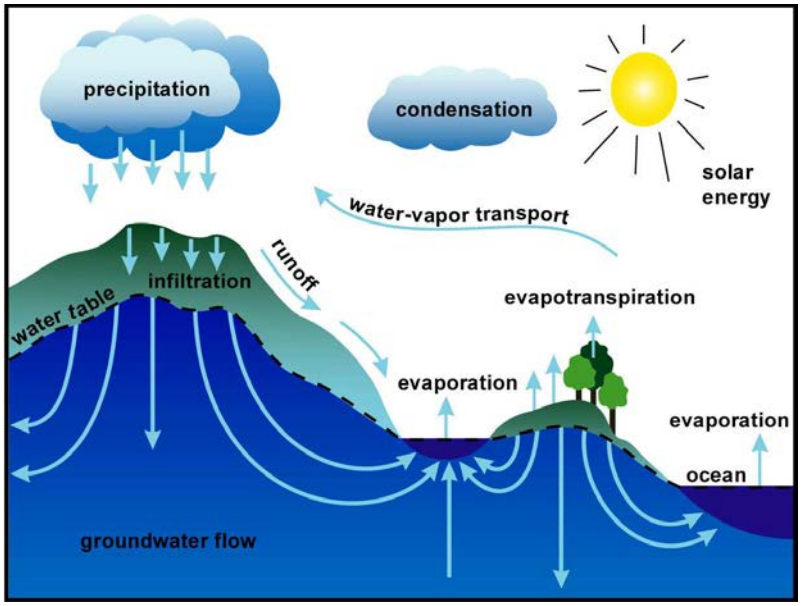
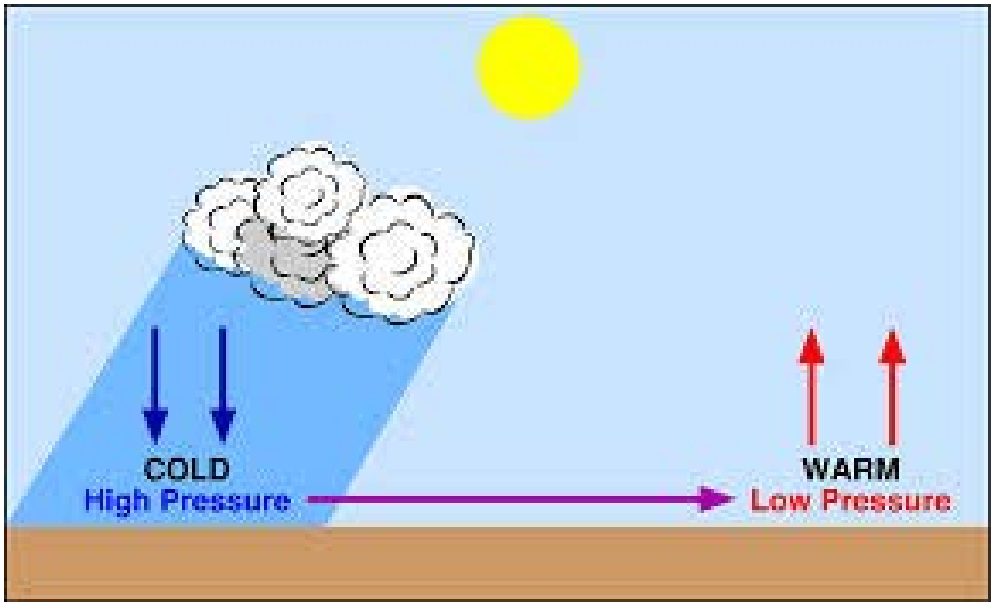
Lecture	Topic
1	Introduction
2	Basic energy sciences
3	Non-Renewables (fossil fuels) & Electricity Generation
4	Nuclear energy and risk assessment
5	Renewable energy (I): Wind and water
6	Renewable energy (II): Geothermal and solar
7	Renewable energy (III): Bioenergy
8	Guest speakers
9	Urban Sustainability: Noise Pollution; Environmental Impacts and Control
10	Urban Sustainability: Infrastructure Systems; Water-Energy-Waste *Nexus Thinking*
11	Waste management
12	Economics and Policy- Circular Economy
13	Review

Symbolic Carbon Cycle Diagram

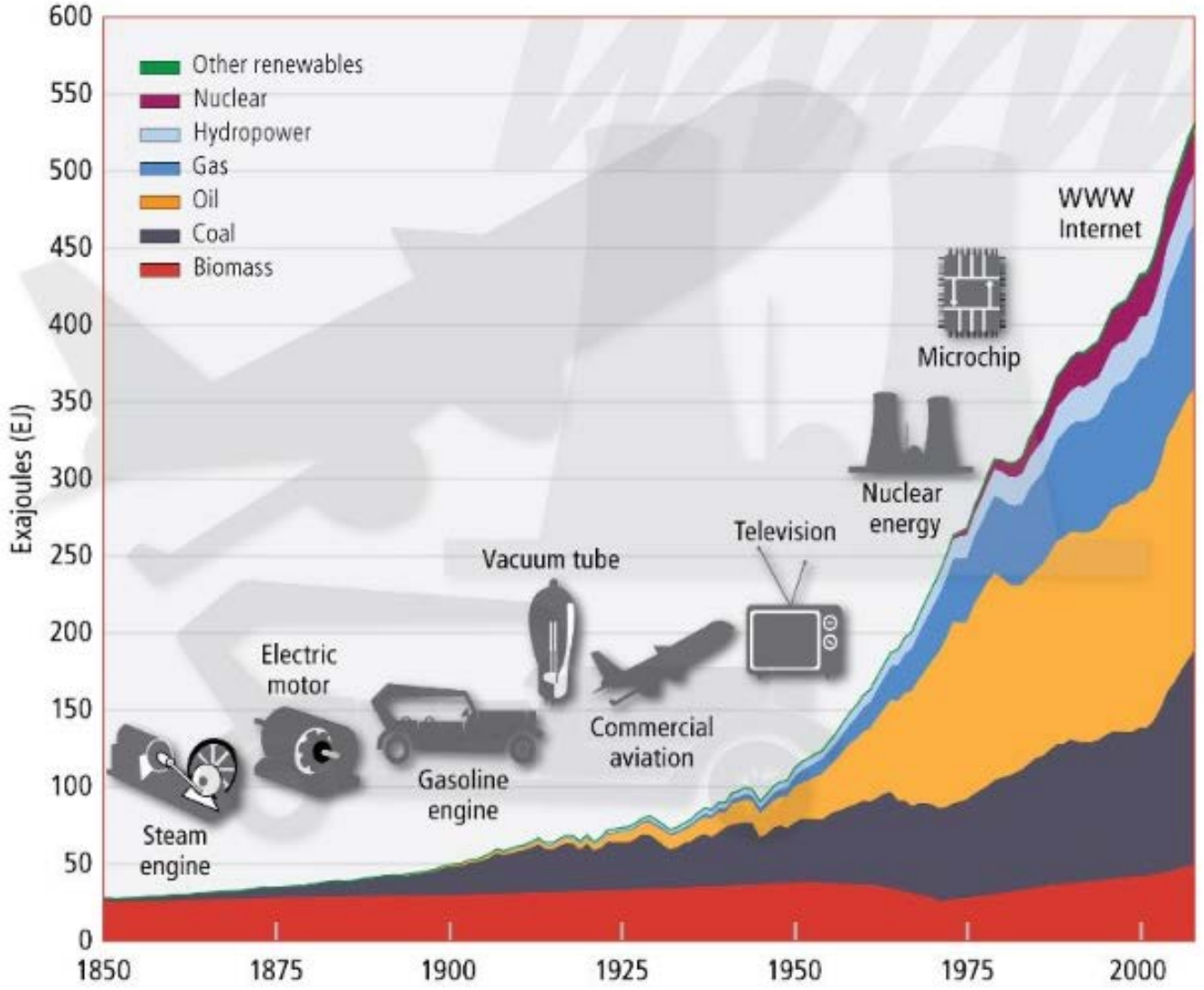


Hydrological Cycle



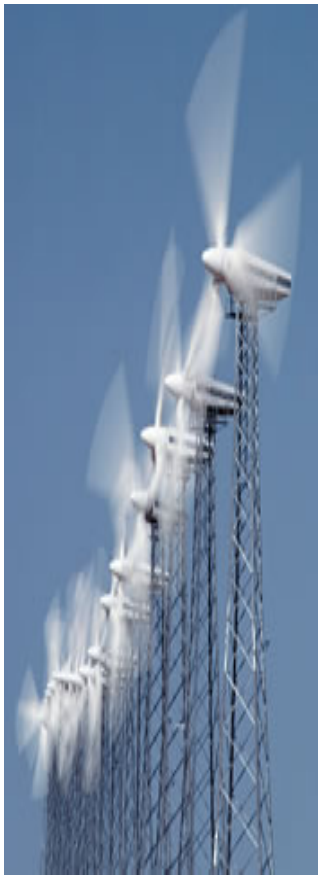


Global Energy Resources



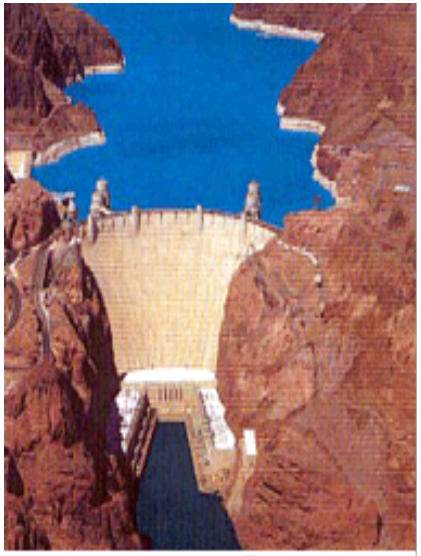
Global Energy Resources

- Obviously the first distinction is into renewable and non-renewable
  - A nonrenewable resource is a natural resource that cannot be re-made or re-grown at a scale comparable to its consumption
  - Renewable resources are natural resources that can be replenished in a short period of time
  - Sustainable???



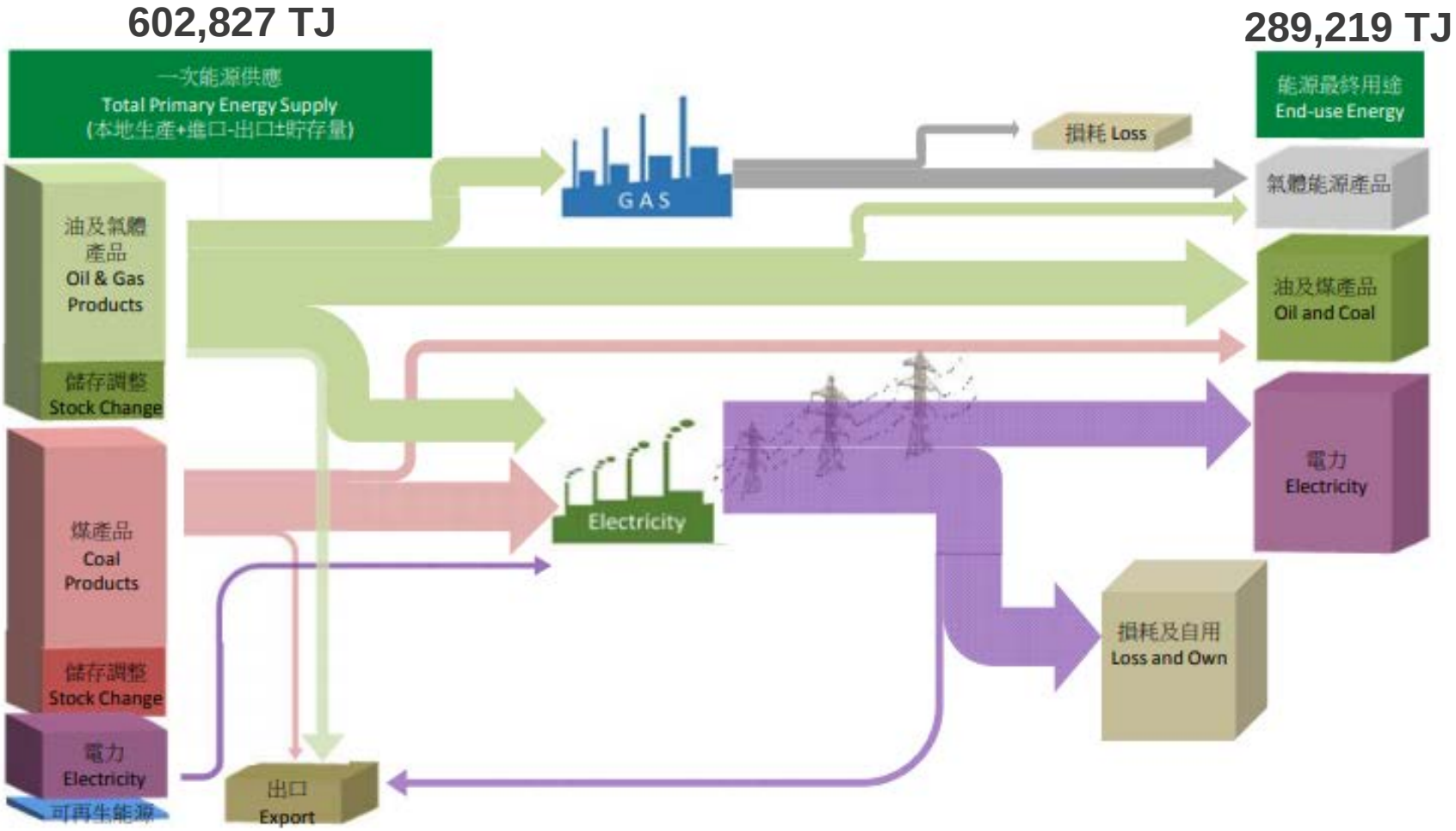
Global Energy Resources

- We are all familiar with examples of each
  - A nonrenewable resource is a natural resource that cannot be re-made or re-grown at a scale comparable to its consumption
  - Nonrenewable
    - Coal
    - Oil
    - Gas
    - Nuclear
  - Renewable
    - Solar
    - Wind
    - Water (Hydro-electric, wave)
    - Biomass
    - Geothermal



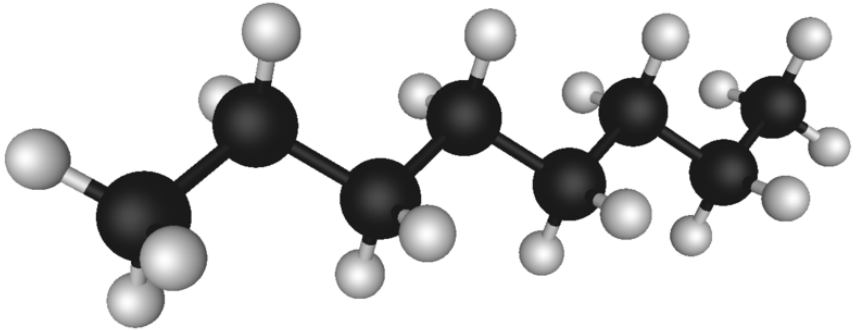
HOOVER DAM

Energy Flows in Hong Kong (2016)



Oil and Gas

- Coal, Oil and Gas are often called "fossil fuels" because they have been formed from the fossilized remains of prehistoric plants and animals
- They are made of a mixture of different hydrocarbons
- Oil and gas have the same origin
  - Decaying microscopic marine life
  - When the plankton dies, it forms an organic mush on the sea bed
  - Under anaerobic conditions (when there is no oxygen) other animal life to feed on the plankton can't be supported and the mush accumulates



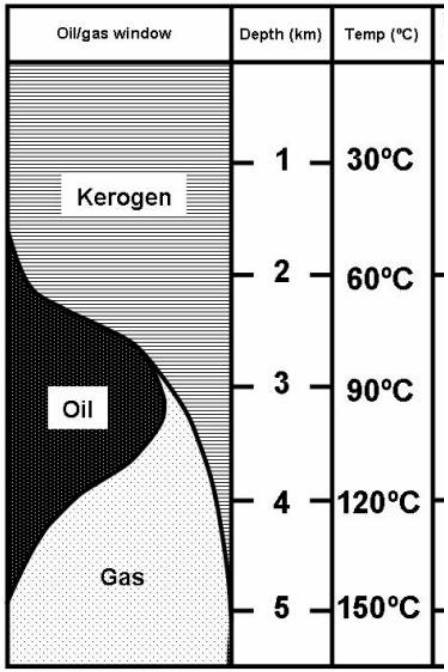
Plant plankton

Animal plankton

Oil and Gas

- When sediment (the sea bed) contains more than 5% organic matter, it is called black shale and it is the pre-curser to hydrocarbon reserves
- As black shale is buried, it comes under more pressure so it is heated
- The depth (and hence temperature of heating) determines if it ultimately becomes kerogen
- As kerogen is heated further, it releases oil and gas
- Shales rich in kerogens that have not been heated to a warmer temperature to release their hydrocarbons may produce oil shale deposits

Black shale deposits



Coal

- Coal currently provides about 34% of the total Hong Kong electricity production (with gas at around 26%)
- Now that oil and gas are dwindling, many energy producers and users are looking again at the potential of coal
- Unlike oil and gas, coal is not formed from marine organisms, but from the remains of land plants
- A swampy setting, in which plant growth is lush and where there is water to cover fallen trees, dead leaves and other plant debris, is ideal for the initial stages to create coal

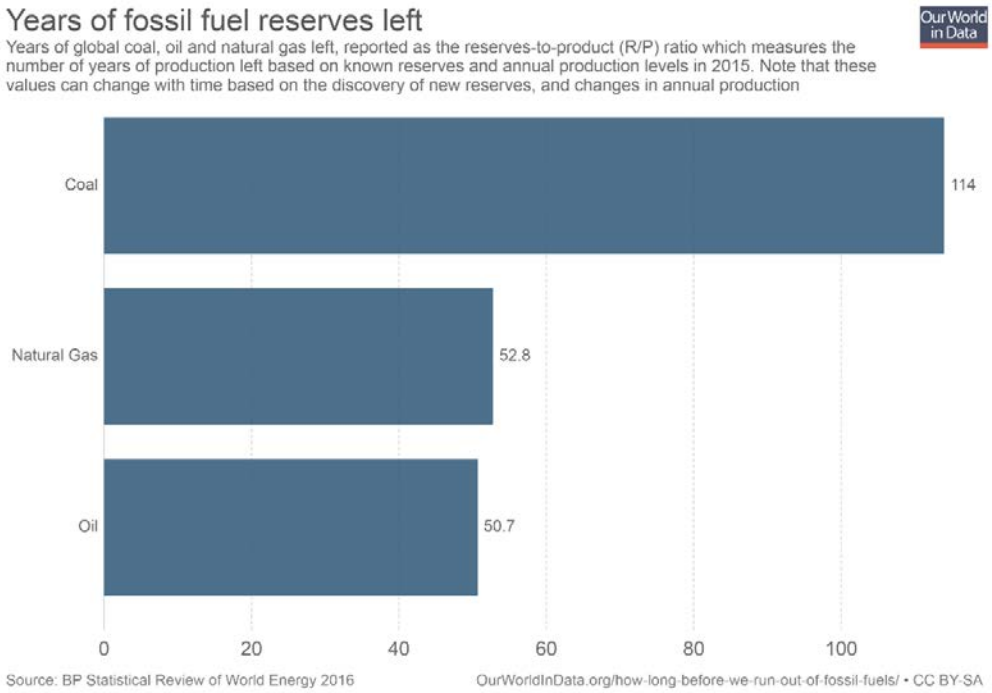
Pro's and Con's of Fossil Fuels

- Pro's
  - Transporting coal, oil and gas to the power stations is easy
  - Fossil fuels are cheap and reliable sources of energy. They are excellent types of fuel to use for the energy base-load, as opposed to some of the more unreliable energy sources such as wind and solar energy

- Con's
  - Basically, the main drawback of fossil fuels is pollution
  - Coal is by far the worst pollutant and has the highest carbon density
  - Burning any fossil fuel produces carbon dioxide, which contributes to the "greenhouse effect", warming the Earth.
  - Burning coal produces sulphur dioxide, a gas that contributes to acid rain.
  - Mining coal can be difficult and dangerous. Strip mining destroys large areas of the landscape

So how much fossil fuel is left?

- **Oil**
  - 1,300 billion barrels of proven reserves still in the ground, worldwide
- **Gas**
  - 6,400 trillion cubic feet of natural gas reserves around the world about the same as having 1,140 billion barrels of oil (BOE), in terms of its energy content
- **Coal**
  - Worldwide, there is roughly 3,100 billion BOE of coal



Uranium

- Uranium is the basis of **nuclear power** which currently produces about 17% of the world's electricity needs
- Uranium is one of the more common elements in the Earth's crust and it can be found almost everywhere in rock, soil, rivers, and oceans
- Uranium ore is processed near the mine to produce "yellow cake", a material rich in U_3O_8
  - 200 tons of this are needed per year for a 1GW nuclear power plant
- Only 0.7% of U in yellow cake is ^{235}U. Most of the rest is ^{238}U which does not work for fission power
  - There is a huge amount of processing to convert yellow cake to useable nuclear fuel
- Whilst some reactors run on unenriched uranium, in most cases it must be enriched so it contains about 5% ^{235}U

Uranium ore concentrate – "yellowcake"

Environment and Non-renewable Energy

Smoggy day in HK

Health implications of air pollution

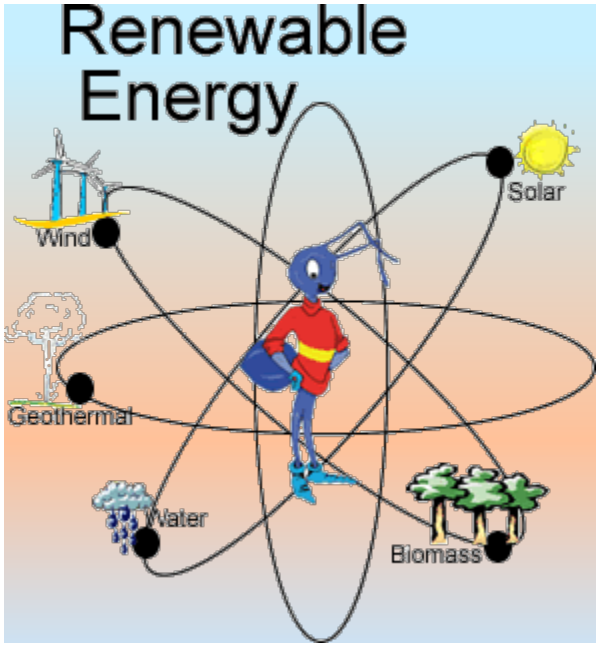
A coal-burning power plant

A petrochemical plant

Nuclear explosion and leakage

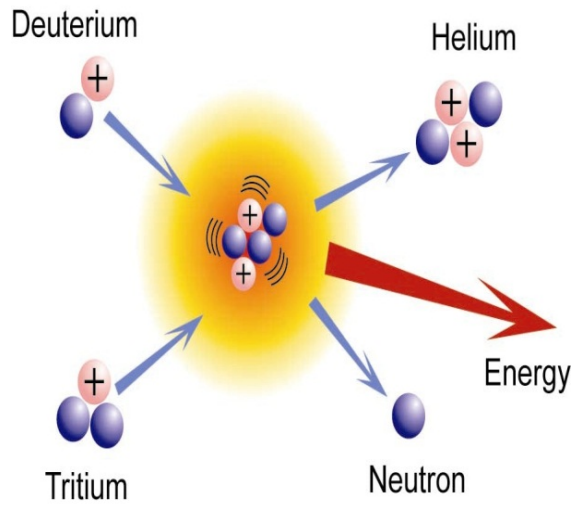
Renewable Energy Resources

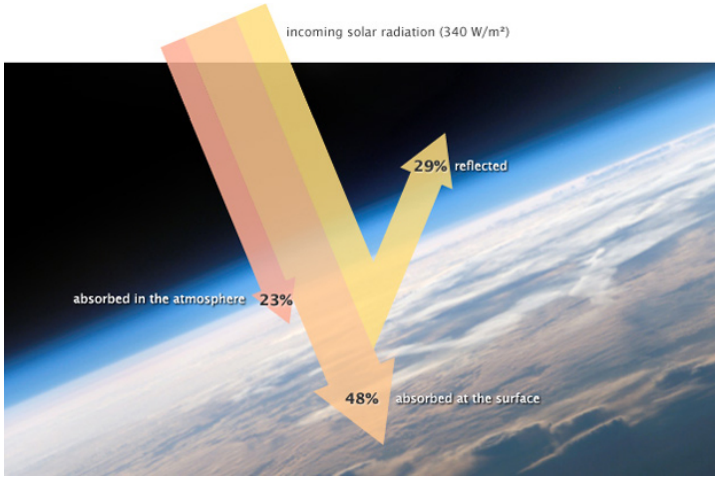
- We will briefly look at renewable energy resources although in theory these are infinite by definition
  - Limitations only come about because of lack of economic viability or technical restrictions
  - We will look in more detail about how energy is produced from these resources later
  - There's no doubt that these will play an increasing role in our energy supply over the next few decades



Solar Energy

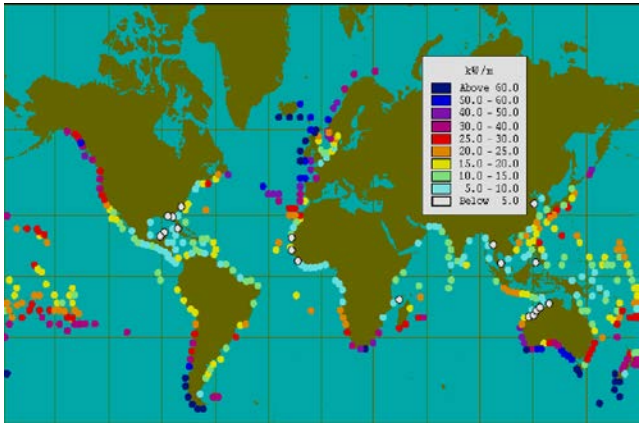
- Solar power comes from thermonuclear reactions in the sun and is the ‘ultimate’ renewable energy source
- We have seen that around 48% of the sun’s energy is absorbed at Earth’s surface
  - Only this is useable
- The potential for exploitation of this resource is massive
  - The amount of solar energy that reaches the Earth’s surface every hour is greater than humankind’s total demand for energy in one year
- There are 2 main principles to exploit solar power
  - Direct heating
  - Photovoltaic cells





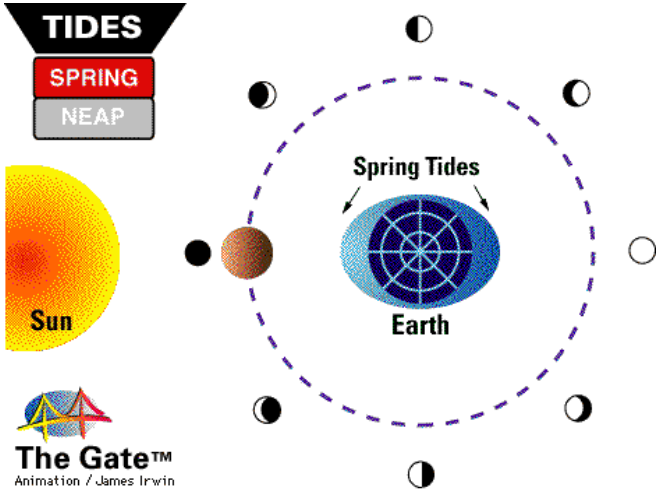
Wave Energy

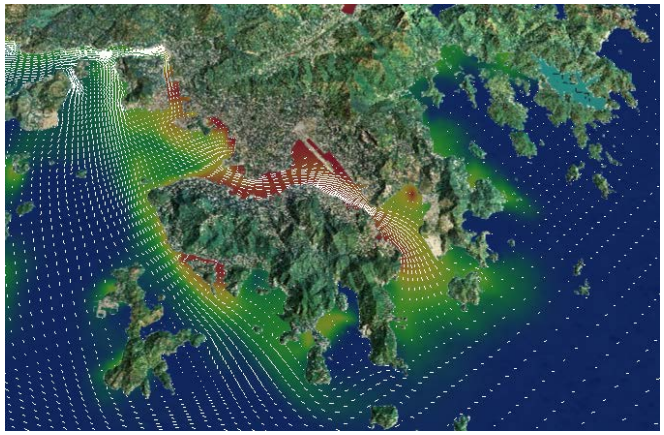
- Among other types of renewable energy, oceans contain energy in the form of waves and tidal currents
- Differential warming of the earth causes pressure differences in the atmosphere, which generate winds
- As winds move across the surface of open bodies of water, they transfer some of their energy to the water and create waves
- The amount of energy transferred and the size of the resulting wave depend on
  - the wind speed
  - the length of time for which the wind blows
  - the distance over which the wind blows
- Therefore, coasts that have exposure to the prevailing wind direction and that face long expanses of open ocean have the greatest wave energy levels



Tidal Energy

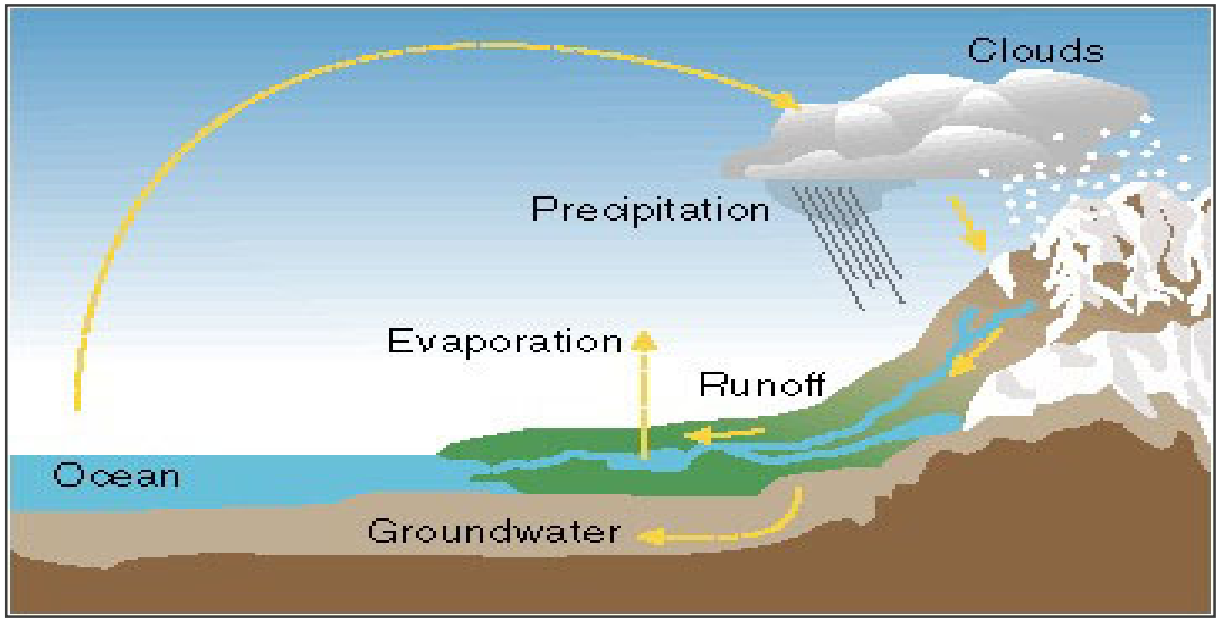
- Tidal streams are created by the constantly changing gravitational pull of the moon and sun on the world's oceans
- Tidal stream technologies capture the kinetic energy of the currents flowing in and out of the tidal areas
- Since the relative positions of the sun and moon can be predicted with complete accuracy, so can the resultant tide. It is this predictability that makes tidal energy such a valuable resource
- Tidal stream resources are generally largest in areas where a good tidal range exists, and where the speed of the currents are amplified by the funnelling effect of the local coastline and seabed, for example, in narrow straits and inlets, around headlands, and in channels between islands





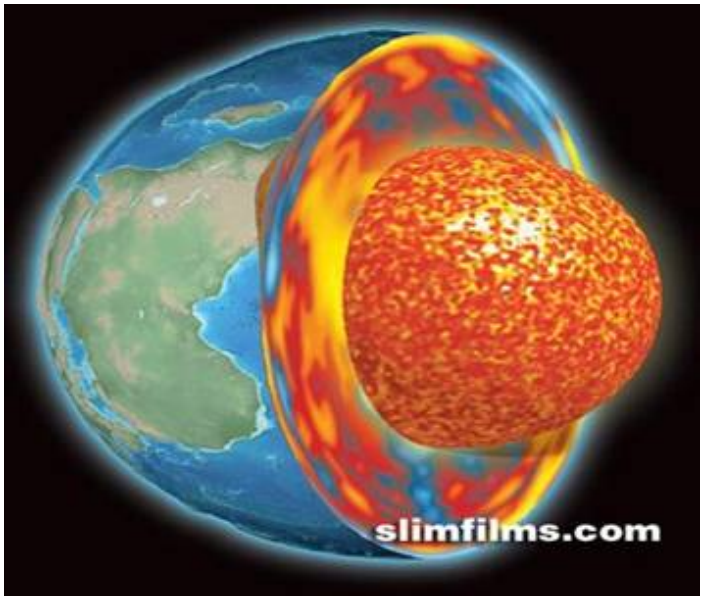
Hydro-Electric Energy

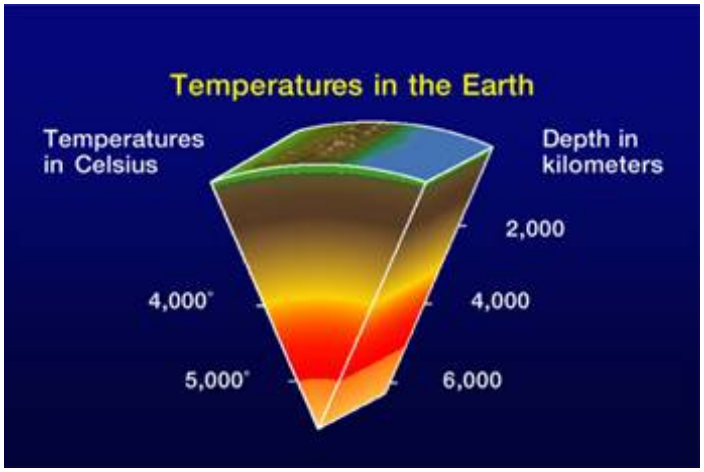
- Hydropower energy is ultimately derived from the sun, which drives the **water cycle**
  - Rivers are recharged in a continuous cycle. Because of the force of gravity, water flows from high points to low points
  - There is **kinetic energy** embodied in the flow of water



Geothermal Energy

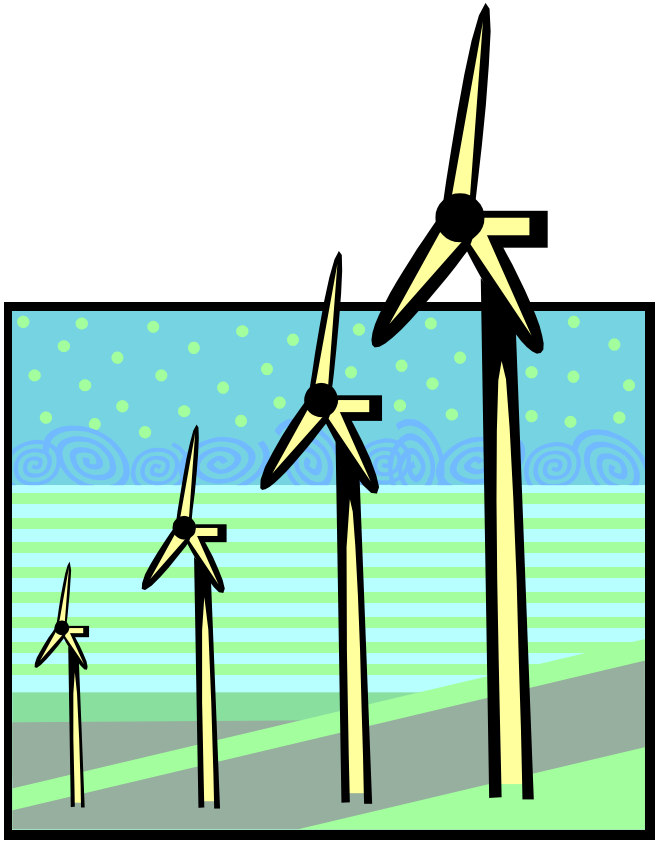
- Geothermal energy is a renewable source
- It is energy ‘stored’ in Earth usually at great depth
- 70% comes from the decay of radioactive nuclei with long half lives that are embedded within the Earth
- Some energy is from residual heat left over from Earths formation
- The rest of the energy comes from meteorite impacts





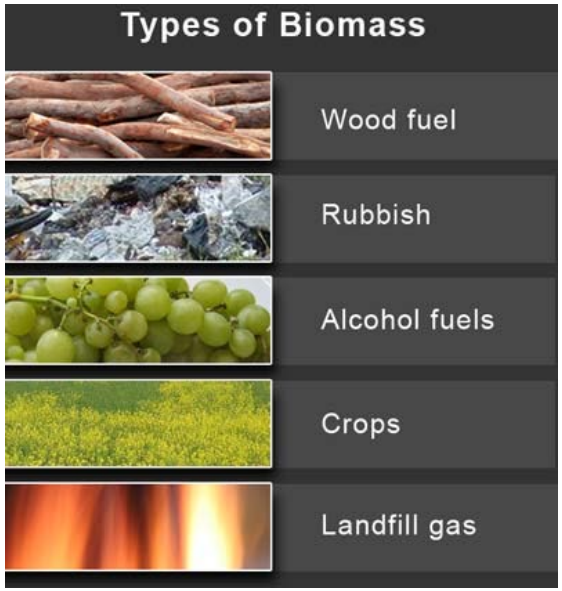
Wind Energy

- Wind energy is essentially a limitless and inexhaustible resource
- Differential heating of the earth's surface and atmosphere induces vertical and horizontal air currents that are effected by Earth's rotation and contours of the land -> WIND
- There is enough power in the wind blowing at any one time on Earth to provide all of our energy needs
  - The practical problems are of building enough wind turbines and finding the area to put them to harness it



Biomass

- Biomass is a renewable energy source that is derived from living or recently living organisms
- Biomass includes biological material, not organic material like coal.
- Energy derived from biomass is mostly used to generate electricity or to produce heat
- Biomass can be sourced locally, from within Hong Kong, on an indefinite basis, contributing to security of supply and has a much lower carbon footprint than fossil fuels
- The waste matter will rot anyway if we don't use it producing methane which is a potent greenhouse gas



A Comparison of Renewables

- There are a number of ways to compare renewables such as cost/kWh, human disruption and so on
- Renewables are *diverse* energy sources
  - They take up space, unlike a fossil or nuclear fueled power station which can produce 1GW in less than 1km^2
  - We can compare the power per unit area of various renewables

POWER PER UNIT LAND OR WATER AREA	
Wind	2 W/m^2
Offshore wind	3 W/m^2
Tidal pools	3 W/m^2
Tidal stream	6 W/m^2
Solar PV panels	5–20 W/m^2
Plants	0.5 W/m^2
Rain-water (highlands)	0.24 W/m^2
Hydroelectric facility	11 W/m^2
Solar chimney	0.1 W/m^2
Concentrating solar	15 W/m^2