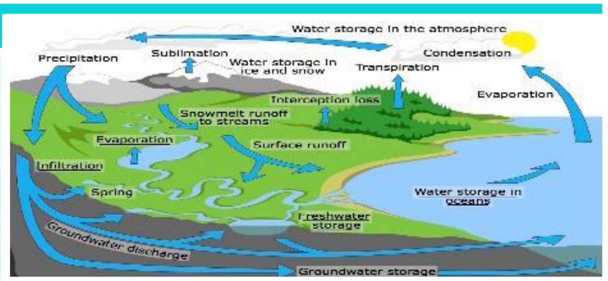
Physical Systems and Suitability: Water Cycle & Water Insecurity

The Hydrological Cycle

The hydrological cycle is a closed system. This means no water is added to the global budget and none is removed. The system is driven by solar energy and gravitational potential energy.

STORE	FLUXES	FLOWS
These are reservoirs where water is held, such as oceans.	This measures the rate of flow between the stores.	The transfer of water from one store to another.

The Global Water Cycle



Water largely exists as **vapour in the atmosphere**. Clouds can contain liquid water or ice crystals.

In the **cryosphere** water is largely found in a solid state, with some liquid form as melt water and lakes.

On the land water is stored in **rivers, streams, lakes** and groundwater in liquid form.

Water is also stored in **vegetation** or in the **soil**.

In the **oceans the vast majority of water** is stored in liquid form, with only a minute fraction held as icebergs.

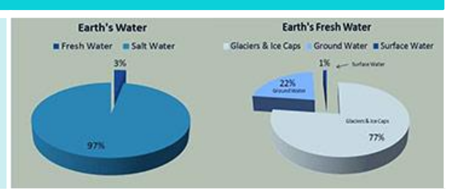
The Global Water Budget

The table shows residence times. This is an average time a water molecule will spend in the reservoir or store. Residence times can impact on the turnover within the water cycle system.

STORES	Volume (10^3 km³)	% of total water	% of fresh water	Residence time
Oceans	1,335,040	96.9	0	3,600 years.
Icecaps	26,350	1.9	68.7	15,000 years.
Groundwater	15,300	1.1	30.1	Up to 10,000 years.
River and lakes	178	0.01	1,2	2 weeks to 10 years.
Soil moisture	122	0.01	0,05	2-50 weeks
Atmospheric moisture	13	0,001	0,04	10 days

Accessible Water for Human Life

Overwhelmingly, **97%** of water is stored in the **oceans**, with only **3%** as **fresh water**. **77%** of this fresh water is **inaccessible and is locked in ice sheets, ice caps and glaciers** found in the high latitude and altitude locations. Another **22% is groundwater**, therefore **leaving only 1% being easily accessible for humans**.



Types of Water

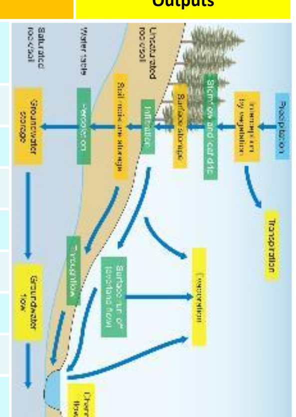
Blue Water	Green Water	Fossil Water
Blue water is the amount of rainfall water that **ends up in rivers, lakes, reservoirs and groundwater**.	The green water is the amount of rainfall that **falls on vegetation**, enters the soil and gets used by the vegetation.	This is an **ancient body of water** that has been contained in an undisturbed space, typically groundwater for millennia.

The Drainage Basin Water Cycle

On a smaller scale the drainage basin is a subsystem within the global hydrological cycle. It is an open system as it has external inputs and outputs that cause the amount of water in the basin to vary overtime.

Input | Flows | Stores | Outputs

Groundwater Storage	Water which is stored underground in permeable rocks. e.g. aquifers.
Precipitation	Moisture falling from clouds as rain, snow or hail.
Interception	Vegetation prevents water reaching the ground.
Surface Runoff	Water flowing over surface of the land into rivers.
Infiltration	Water absorbed into the soil from the ground.
Percolation	When water moves downwards through the soil.
Transpiration	Water lost through leaves of plants.
Through Flow	When rainfall or water flows through the land.
Evaporation	The process in which a liquid changes state and turns into a gas.



Drainage Basin

A drainage basin is an area of land drained by a river and its tributaries.

The boundary of the drainable basin is defined by the **watershed** (the highland which divides and separates water flowing to different rivers). Drainage basins **can be any size**, from a small stream to major rivers across international boundaries.

This is important as drainage basin size can influence the length and the amount of **discharge held** in a river basin.

Human Impacts on the Drainage Basin

Dams	Urbanisation	Agriculture	Deforestation or afforestation	Abstraction of water
Dams can be built to generate hydro-electric power and fresh water supplies.	Urbanisation can increase surface runoff and water usage.	Rivers can be diverted for irrigation in agriculture.	Deforestation or afforestation can change storage levels.	Abstraction of water for domestic/industry reduces flows.

Physical Impacts on the Drainage Basin

Climate	Soils	Geology	Relief	Vegetation
Climate has a role in influencing the type and amount of precipitation. Also it influences the amount of evaporation.	Soils determine the amount of infiltration and throughflow directly and indirectly. Also types of vegetation.	Geology can impact on subsurface processes such as percolation and groundwater flow.	Relief can impact on the number of precipitation. Slopes can affect the amount of runoff.	Presence/absence of vegetation can impact interception, infiltration, overland flow and transpiration.

CASE STUDY: Amazon Drainage Basin

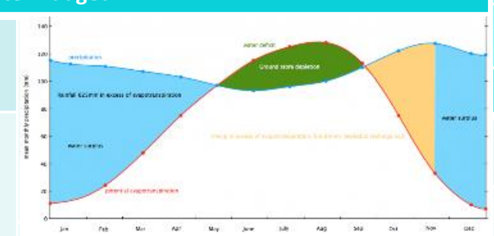
The Amazon basin is the world's largest at 6 million km². The basin contains the world's largest area of tropical rainforest. The climate experiences high precipitation rates and average temperatures, with little seasonal differences. Around 50-60% of precipitation in the Amazon basin is recycled by evapotranspiration.

The rainforest's trees play a crucial role in the water cycle. This is done by absorbing and storing water from the soil & releasing it through transpiration. However, recent deforestation has disrupted the drainage basin cycle with:

- Less precipitation
- More surface runoff and infiltration
- More evaporation, less transpiration
- More soil erosion and silt being fed into the rivers.

The Water Budget

This is the annual balance between inputs (precipitation) and outputs (the channel flow and evaporation).



The water budget shows the times when water naturally enters and leaves the system:

- When there is more than enough water (this is called a **positive water balance**).
- When there is not enough water (this is called a **negative water balance**).

This is useful as it shows times for a **potential drought**. A drought would create challenges to human consumption, agriculture, health etc.

Equation to calculate a water budget:
Precipitation (P) = channel discharge (Q) + evapotranspiration (E) + change in storage (S)

River Regimes

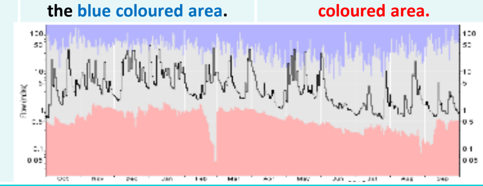
This is the annual variation in the discharge or flow of a river at a particular point. It is measured using cumecs.

The main factors that affect the regime of the river are:

- Drainage basin area
- Temperatures, with possible meltwater and high rates of evaporation in the summer.
- Variation in altitude
- Geology and soil, particularly their permeability.
- Mean annual precipitation and discharge rates.
- Main land use, such as urbanisation or forests.
- Human activities aimed at regulating a river's discharge such as dams.

The highest flow is shown by the bottom of the blue coloured area.

The lowest flow is shown by the top of this red coloured area.



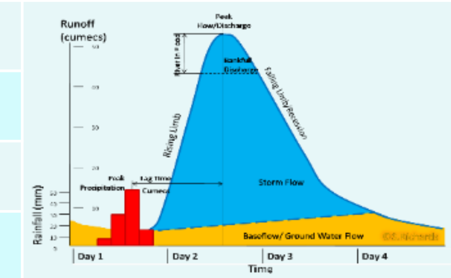
CASE STUDIES: Different River Regimes

Amazon River *South America*	Yukon River *North America*	River Nile *Africa*
Humid tropical climate based by ancient shield rock. Peak discharge in April-May and-lowest in September. Linked to wet and dry seasons and Andean snowmelt.	Tundra climate which flows through a mountain range. In winter the temperature drops so water freezes. In summer, meltwater is a sudden input into the system.	Warm, arid climate. Huge drainage basin. In 1970, the Aswan Dam significantly altered the regime. Flow reduced by around 65% and the seasonal flow was changed.

Storm Hydrographs and River Discharge

River discharge is the volume of water that flows in a river. Hydrographs show discharge at a certain point in a river changing over time in relation to rainfall

1. **Peak discharge** is the discharge in a period of time.
2. **Lag time** is the delay between peak rainfall and peak discharge.
3. **Rising limb** is the increase in river discharge.
4. **Falling limb** is the decrease in river discharge to normal level.



Factors affecting the Shape of a Storm Hydrograph

Shape	Topography	Vegetation
Circular basins have shorter lag times when compared to elongated basins which have longer lag time.	Steep slopes promote surface runoff, whereas gentle slopes allow for infiltration and percolation.	Deciduous trees in winter means low levels of interception than compared to the summer. This also causes more evaporation.
Soil	**Geology**	**Human activity**
Clay has low infiltration rates when compared to sandy soils which have a much higher infiltration rate.	Impermeable rocks, such as granite, restricts percolation and increases surface runoff in comparison to limestone.	Urbanisation has impermeable (concrete and tarmac) surfaces. Natural landscapes will have fewer of these surfaces.

Storm Hydrographs and Players

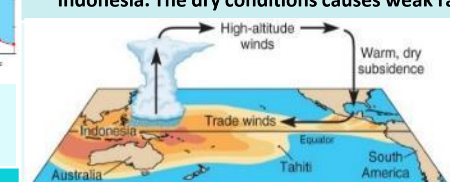
Urban planners will aim to manage the impacts of flood risks due to **populations being in proximity to rivers**. Therefore planners will explore options such as strengthening embankments, implementing emergency procedures and avoiding any new developments on known floodplains.

Types of Drought

Meteorological drought	This happens where long-term precipitation is lower than normal. It changes for different regions as it is affected by the atmospheric conditions.
Agricultural drought	This happens when there is not enough soil moisture to allow enough crops to grow. It is caused by precipitation shortages, changes in rates of evapotranspiration and reduced groundwater levels.
Hydrological drought	This happens when the amount of surface and subsurface water (rivers, lakes, reservoirs and groundwater) is deficient. It is caused by a lack of precipitation and usually occurs after meteorological and agricultural drought.
Socio-economic drought	This occurs when water demand outstrips the water availability. This could be caused by a lack of precipitation or by human overuse of water sources.

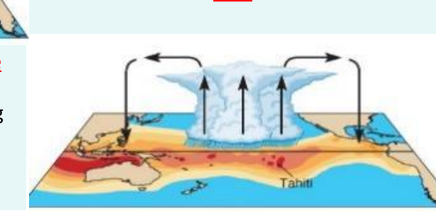
Physical Causes of Drought: El Nino Effect

El Nino can trigger very dry conditions throughout the world, especially in Australia and Indonesia. The dry conditions causes weak rains and monsoon failure in India and SE Asia.



Normally, warm ocean currents off the coast of Australia cause moist warm air (low pressure) to rise and condense causing storms and rain over Australia.

In an El Niño year (every 2-7 years) the cycle reverses. Cooler water off the coast of Australia reverses the wind direction leading to dry, sinking air (high pressure) over Australia. This creates hot weather and a very low amount of rainfall.



Sometimes following an El Nino event are La Nina episodes. They involve the build up of cooler than usual subsurface water in the tropical part of the Pacific. This reversal can lead to severe droughts in western parts of South America and wet conditions in Eastern Australia.

Human Activity on Drought

Agriculture	Dam Construction	Deforestation
Using large amounts of water to irrigate crops can remove water stored in lakes, rivers and groundwater. Some crops require more water than others. Finally, overgrazing can destroy vegetation cover.	Large dams can be built across a river to produce electricity and store water in a reservoir. This can reduce river water naturally flowing downstream. This can create drought conditions downstream from the dam.	This can reduce the amount of water stored in the soil as rain tends to fall and wash off the land as surface run-off. This causes the ground to become vulnerable to erosion and desertification.

Ecological Impacts of Drought

Wetlands
A deficit of water can lead to the **drying out** of wetland habitats. Since such habitats support a great variety of flora and fauna, the survival of all these life forms becomes difficult when there is a deficit of water.

Forests
The absence of precipitation and dry foliage. If temperatures are high, this foliage can catch fire. **Wildfires** are highly common during droughts. In the absence of rainfall to extinguish any fires, wildfires can destroy vast areas.

Desertification
Droughts can accelerate **desertification** caused by overgrazing, deforestation, and other human activities. The lack of water further kills plants, leaving little chance for the land to recover.

Wildlife Migrating
The lack of water and food during droughts forces **wildlife to migrate** to where vital resources are available. However, many animals die during such journeys. Those reaching better habitats often die after failing to adjust.

Biodiversity
Most plants and animals living in areas that are experiencing severe drought are unable to survive. As a result, entire populations of a **species can be wiped out** from an area. Thus, drought-affected areas exhibit a great loss of biodiversity.

Dust Storms
In the absence of water, soil dries up and becomes susceptible to **wind erosion**. Thus, droughts often trigger dust storms, which in turn negatively affects the plant and animal life. Dust storms can also affect human health.

Ecological Resilience

The capacity of an ecosystem to withstand and recover from a natural event or human disturbance.

CASE STUDY: Drought in Australia (The Big Dry) 2006

Causes
Drought in Australia is often caused by a weather pattern in the Pacific Ocean known as El Niño. In an El Niño year (every 2-7 years) the cycle reverses. Cooler water off the coast of Australia reverses the wind direction leading to dry, sinking air (high pressure) over Australia causing hot weather and a lack of rainfall.

Short-term Effects
- **Urban areas** suffered a major water shortage.
- Critical **reservoirs dried up**.
- **Crop failure** and dried vegetation.
- **Animals die** from starvation and dehydration.

Long-term Effects
- Crop failure led to **financial losses** for farmers
- **Suicide rates** amongst farmers soared**.**
- Number of **sheep** in Australia **fell by 6 million**.
- **Vegetation loss** and soil erosion lead to rivers and lakes suffering with outbreaks of toxic algae.

Short-term Management
- **Water conservation measures** were introduced. The 3 million people who rely on the River Murray for their water allocation reduced.
- The Australian government provided over 23,000 rural families and 1500 small businesses with **income support.**

Long-term Management
- Investment into improving **drought forecasts** so that farmers can prepare better, **improving irrigation systems**, and **drought resistant crops**.
- Large-scale **recycling of grey water**.
- **Construction of desalinisation plants** and devising new water conservation strategies.

Types of Flooding

Groundwater Flood
Flooding that occurs after the ground has become saturated from prolonged heavy rainfall.

Flash Flood
Occurs when intense rainfall has insufficient time to infiltrate the soil, so flows overland.

Surface Water Flood
A flood with an exceptionally short lag time –often minutes or hours.

Physical and Human Causes of Flooding

Prolong & heavy rainfall
Long periods of rain causes soil to become saturated leading runoff.

Geology
Impermeable rocks causes surface runoff to increase river discharge.

Earthquakes
Can cause the failure of dams or landslides that can block rivers.

Relief
Steep-sided valleys channels water to flow quickly into rivers causing greater discharge.

Land Use
Tarmac and concrete are impermeable. This prevents infiltration & causes runoff.

Jokulhlaups
When volcanic activity generates meltwater beneath ice sheets that is suddenly released.

Dams
Blocks the flow of sediment which can lead to increased river bed erosion downstream.

Vegetation
High vegetation cover will create higher rates of interception, storage and evapotranspiration.

Channelization
Improves river discharge but could simply displace the flood risk to a location downstream.

Impacts of Flooding

Socioeconomic
- x Deaths & injury
- x Water-borne diseases
- x Property damage
- x Disruption to infrastructure
- x Interruption of utilities
- x Destruction crops/livestock

Environmental
- ✓ Connectivity of aquatic habitats
- ✓ Soil replenishment
- x Eutrophication of water bodies
- x Leach pollutants into rivers.
- x Disease carried by floodwaters

CASE STUDY: Lincolnshire Flood 2019

Causes
On 12th June 2019 the River Steeping burst its banks causing flooding in and around Wainfleet. An equivalent of about two months' rain fell in two days.

Effects
Crops were destroyed.
130 properties flooded.
590 people forced out of their homes.
An animal park was forced to close temporarily after being flooded.

Responses
Social media used to inform people about evacuation.
An emergency centre set up in nearby Skegness.
340 tonnes of ballast were dropped by RAF helicopters to plug breach in a levee.

Impact of Climate Change on the Hydrological Cycle

The International Panel of Climate Change predict that as a result of increased greenhouse gas emissions, there will be considerable changes to the inputs, outputs and stores within the hydrological cycle.

Increasing convection and evaporation.	Increased condensation and cloud cover.	Increased precipitation in the tropics and mid-latitudes.
Decreased snow, permafrost and ice cover. Increase in meltwater will increase river flooding.	Decreased humidity and precipitation in certain locations e.g. subtropics.	Less accumulation of glacial ice because more precipitation is falling as rain.
Increase in high-pressure systems.	Increased flood risks in the tropics and mid-latitudes.	Increasing incidence and severity of drought events.

Climate Change Future Trends – more rain and more drought

- **2010 was the wettest year ever recorded**; heavy precipitation increased the incidence of flooding.
- **Economic losses** from hydrological disasters have grown quickly.
- Flood figures do not show an **upward trend of flooding**, however they do show more extremes.
- **Droughts have become more widespread and severe**. More intense droughts have affected more people.
- ENSO also plays a role; This can **destabilise atmospheric conditions** and set the stage for the increase in precipitation and flooding events.

Water Insecurity

This is defined as the lack of a reliable source of water, of appropriate quality and quantity to meet the needs of the local human population and environment.

Water Stress
When demand for water is greater than the amount of water available (1,000-1,700m³ per capita) , and when water is of poor quality and restricts usage.

Water Scarcity
Water scarcity is the lack of sufficient available water resources (500-1,000m³ per capita) to meet the demands of water usage within a region.

Absolute Water Scarcity
When renewable water resources are extremely low (less that 500m³ per capita) then there is widespread restriction on use.

Causes of Water Insecurity

There are a number of factors that reduce the amount of water that is eventually available for human use. It is worth noting that many physical causes are augmented by ever increasing human activities.

Physical	Human
Climatic Variations This will increase in severity, affecting rates of aquifer recharge, glacial ice loss and precipitation patterns.	**Over-abstraction of groundwater** 20% of global aquifers are over-used, limiting their capacity to sufficiently recharge - which increases future water insecurity.
Eutrophication Bacteria blooms in warm water causing death of living organisms, and pollutes the water - making it unsafe for consumption and will increase water stress.	**Pollution and Contamination** Runoff from agriculture (chemical fertilisers + pesticides), industries and, untreated sewage and urban runoff is transported to water sources.
Sedimentation Slower rates of flow (and lower water levels) encourage sedimentation, which reduces water quality.	**Population Increase** As greater levels of agriculture, industrialisation and growing living standards place stress on water sources.
Salt water encroachment As different water densities do not mix, saltwater rises (as freshwater is extracted), contaminating soil and water sources in coastal areas.	**Rising living standards** Greater domestic demand for water, higher meat consumption and higher electricity demands (many forms of electricity generation require large quantities of water).

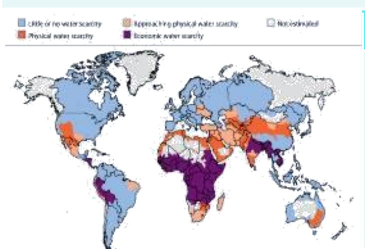
Risks and Consequences of Water Insecurity

Nearly 20% of the global population live in areas of water scarcity. This is due to many factors, including low rainfall, climate change affecting rainfall patterns and reliability and human activities such as **land use change, soil degradation, industry and agriculture**. Collecting, storing, purifying and distributing water is **expensive**. In many places (such as Ethiopia), people suffer from **economic**

Physical and Economic Water Scarcity

Physical Scarcity
A quantity problem exists where there is not enough water to meet its demand. Physical water scarcity is prevalent in arid regions and can be tackled by adopting good water conservation policies.

Economic Scarcity
A quality problem exists where there is not enough technology to utilize existing sources of water. For instance, water resources are plenty but the technological capacity to harness them does not exist.



Water Supply and Economic development
Economic development is one of the main drivers of the increasing demand for water. **Agriculture (70%)** is dominant over water use, particularly for irrigation. In addition, **industry and energy (20%)** depend on a reliable supply of water for the production of goods but also in generating HEP or as cooling water within power stations. Finally, **domestic use (10%)** has been increasing as standards of living rises. This includes having safe & sufficient supply of water for washing & food preparation.

Water Conflicts

When the demand for water overtakes the available supply and there are key stakeholders desperate for that water, there is potential for conflict, otherwise known as 'water wars'.

CASE STUDY: Nile River Conflict

Location and Background
Located in Africa, the Nile is the **world's longest river** (6,700km) and no less than **11 countries** (e.g. Sudan, Egypt, Ethiopia and South Sudan) and **300 million people** are competing for its water. Importantly, many of these countries are amongst the poorest in the world.

Issues and Concerns
Egypt is entirely dependent on the Nile for its water supply. They regard any reduction as a **national security issue** and against the agreements of **1959 Nile Water Treaty**. With the construction of dams downstream in Ethiopia (such as the **Gran Renaissance Dam** on the Blue Nile) a potential flash point has emerged due to the possibility of a **reduction** in annual flow. Both Egypt and Ethiopia has seen **rapid population growth** and seek to become more **economically developed**. Therefore access to safe and sufficient water will be critical in the future.

Managing Water Supply

Hard Engineering Methods of Water Supply

These projects involve high levels of capital and technology. However, these projects have various questions as to their environmental and social costs.

Water transfer schemes	Mega dams	Desalination
This involves the diversion of water from one drainage basin to another.	Large rivers are impeded, stored, rechanneled and re-engineered to redesign the natural flow.	Converts saltwater from the oceans into useable freshwater on a large scale
Example: The South-North water Transfer project, China.	**Example: The Three Gorges Dam, China**	**Example: Israel, Saudi Arabia and Australia**

Sustainable Methods of Water Supply

This is using methods that are more natural or minimizing wastage and pollution of water resources. It also aims to ensure all viewpoints are expressed and water is safe but affordable.

Restoration	Rainwater Harvesting	Filtration Technology
Restoring damaged rivers, lakes and wetlands to support the natural hydrological cycle.	Collecting rain falling on roofs in butts for flushing or watering plants.	Ensuring that water is physically purified and recycled to a safe, drinkable standard.

CASE STUDY: Sustainable Water Management in Singapore

The 5.4 million residents of Singapore are urban, thus demand is high. To ensure sustainable water supplies, they have used several methods:
- Metering water supplies so people cannot waste water.
- Public education to reduce water use.
- Cutting water leaks to 5% (UK leakage is 20%).
- Water prices which rise and fall with usage.
- Subsidies which protect the poor from expensive water.
- Rainwater collection.

Integrated Water Resource Management (IWRM)

This approach aims to create a framework for coordination in which all PLAYERS, at all scales are involved in water management. The aim to for these players to work together in order to effectively develop policies and strategies to achieve a common approach to land, water and resource management. This is important in avoiding future 'water wars'.

CASE STUDY: Colorado Integrated River Management

The Colorado river flows **2,330km** from the **Rocky mountains** to the **Gulf of California.** However the river is prone to the effects of **drought, urbanisation, population growth and agricultural needs**. Despite some previous attempts for regulation, there **still isn't enough**. This has therefore caused disputes. Since the 1990s, there have been environmental protection laws, such as the **Grand Canyon Protection Act 1992**. Now individual states have been forced to explore alternatives. For example, Nevada has negotiated for **extra water allocation** (especially for Las Vegas) and California is investing in **desalination**.

Water Sharing Treaties and Frameworks

Despite the threat of military conflict over water, there has actually been very few 'water wars'. Instead there has been **far more international cooperation**. Examples of important international agreements includes;
- **The Helsinki Rules** with their equitable use and shares concepts.
- **UN Water Course Convection** which sets guidelines for the protection and use for transboundary rivers.

Physical Systems and Suitability: Carbon Cycle and Energy Security

The Carbon Cycle

The exchange of carbon between the atmosphere, terrestrial biosphere, oceans and sediments.

Carbon Stores and Fluxes

Stores	Fluxes
Function as sources (adding to the atmosphere) and sinks (removing from the atmosphere).	**Movements of carbon from one store to another; provide the motion in the carbon cycle.**
Examples: Atmosphere, Coal, Oil and Gas, Sedimentary Rocks, Surface and Deep Ocean, Plants and soil	Examples: Photosynthesis, Erupting volcano, Decomposition, Respiration, Burning Fossil Fuels.

Slow Carbon Cycle	Fast Carbon Cycle
Carbon held in sediment on the floor of the oceans can be stored for an extremely long time.	The **terrestrial part of** the carbon cycle involves photosynthesis, respiration and decomposition of plant matter.

Measuring Carbon	The amount of carbon on Earth is colossal. Dealing with units such as grams and kilograms is far too complicated, so carbon is measured in a unit called Pentagrams (Pg)	= A billion tonnes (1,000,000,000t)

The Geological Carbon Cycle

Carbon that moves between rocks and minerals, seawater, and the atmosphere can create rock formations such as limestone and chalk.

Acid rain dissolves rocks rich in carbon, causing chemical weathering and releasing bicarbonates.

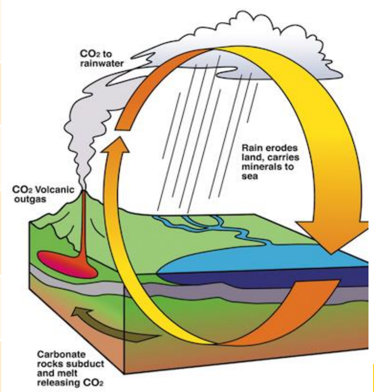
Carbon sediments are transported to the oceans via rivers. They are then deposited.

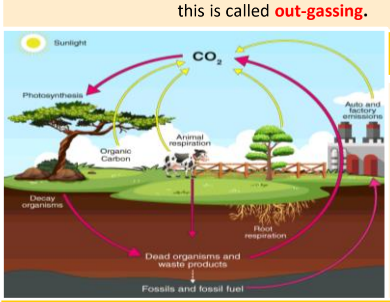
Carbon in organic matter (plants, animal shells and skeletons) sinks to the ocean floor, building up layers of chalk and limestone.

Heating along subduction boundaries alters sedimentary rocks, creating metamorphic rocks. This releases CO_2 from rocks which are carbon rich.

Rocks containing carbon get subducted at boundaries and re-emerge in volcanic eruptions.

Terrestrial carbon is released through volcanic eruptions as CO_2 – this is called **out-gassing**.





The Bio-geochemical Carbon Cycle

This is carbon cycling through the process of photosynthesis, respiration, decomposition and combustion. Here, carbon is stored in oil, coal and natural gas.
The amount of carbon released or stored is determined by these biological and chemical processes.

Living organism are critical in maintaining this system because they control the balance between storage, release, transfer and absorption of carbon.

Carbon Sequestration

The removal and storage of carbon from the atmosphere. It occurs through photosynthesis and is held in oceans, forests and soils. It is crucial because it prevents too much carbon being in the atmosphere and helps to regulate the planetary temperature balance.

Oceanic Sequestering

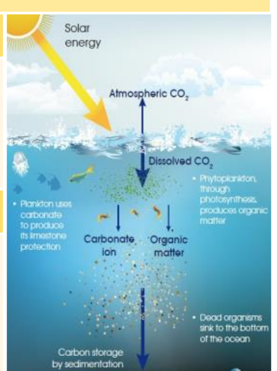
Oceans are the Earth's largest carbon store. They store 50 times more than that of the atmosphere. Most of the oceanic carbon is stored in marine algae, plants and coral. The rest occurs in dissolved form.

The Biological Pump

This is the ocean's biologically driven sequestration of carbon from the atmosphere to the **ocean interior** and **seafloor sediments**. It is the part of the oceanic carbon cycle responsible for the cycling of organic matter formed mainly by **phytoplankton** during photosynthesis, as well as the cycling of calcium carbonate formed into shells by certain organisms such as plankton.

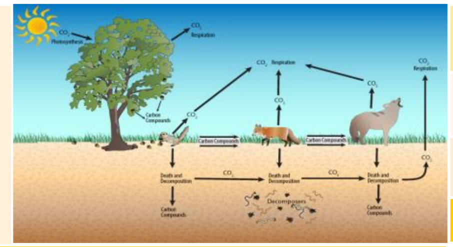
The Thermohaline Circulation

This is a **giant ocean conveyor belt** that keeps the carbonate pump working. This moves carbon compounds to different parts of the ocean in downwelling and upwelling currents. **Downwelling** occurs in ocean areas where the cold, dense water sinks. As the cold deep ocean water begins to increase in temperature, it **upwells** to the ocean surface, some of the dissolved carbon dioxide is released back into the atmosphere.



Terrestrial Sequestering

Plants sequester carbon out of the atmosphere during photosynthesis. When animals eat plants, carbon sequestered in the plant becomes **fat and protein**. **Respiration** by animals will return some of this carbon back to the atmosphere.
On land, **soils are the biggest carbon stores**. They are stored here as **dead organic matter** and can be **stored for decades or longer**, before being **broken down by microbes** and either **used by plants** or released into the atmosphere.



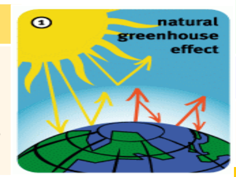
Tropical Rainforest as Carbon Stores: The Amazon Rainforest

Tropical forests are very important stores of carbon. For instance, the Amazon forest covers an estimated 5.3 million sq km and holds 17% of the global terrestrial vegetation carbon stock.
If left untouched, the Amazon forest takes in more carbon dioxide than it puts back into the atmosphere. However, due to the effects of deforestation, tropical forests are becoming less efficient at trapping carbon.

The Greenhouse Effect

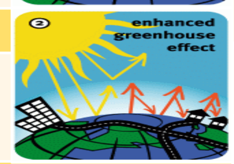
Natural Greenhouse Effect

The Earth is kept warm by a natural process called the Greenhouse Effect. As solar radiation hits the Earth, some is reflected back into space. However, greenhouse gases help trap the sun's radiation. Without this process, the Earth would be too cold to support life. This is because average temperature would be -18°C instead of the current +15°C.



Enhanced Greenhouse Effect

Since the industrial revolution, there has been an increase in humans burning fossil fuels for energy. Burning these fuels emit extra greenhouse gases. This is making the **Earth's atmosphere thicker**, therefore trapping more solar radiation and causing less to be reflected. As a result, our Earth is becoming warmer.



Effects on Precipitation and Temperature

Greenhouse gases naturally help to maintain the Earth's temperature, and therefore determines the distribution of temperature and precipitation. Changing their concentration is likely to alter these patterns.

Carbon Regulation

Oceanic and **terrestrial photosynthesis** plays an important role in regulating the composition of the atmosphere. On land, a key factor is **soil health** which in turn will create more **biomass** to support more carbon being sequestered from the **atmosphere**.

Soil Health	Atmosphere
Healthy soil will enhance ecosystem productivity. This will increase the storage of carbon within biomass and ensure more carbon is sequestered from the atmosphere. Once plant residue is added to the soil, organisms will convert it into CO_2. This will gradually remove it from the atmosphere.	Greenhouse gases absorb radiation from the sun and help the Earth to maintain its temperature. Photosynthesis organisms play an essential role in helping to keep CO2 levels relatively constant, thereby regulating global average temperatures. Photosynthesis is highest where it is warm & wet.

Fossil Fuel Implications

Fossil fuels (oil and gas) have been burnt to provide energy and power at increasing rates since the beginning of the Industrial Revolution. **Fossil fuel combustion** is the number one threat to the global carbon cycle. It is changing the balance of both the **carbon stores** and **fluxes**.

Ecosystems

- Ecosystems will see a decline in the goods and services they provide.
- There will be a decline in biodiversity and a rapid change in the distributions of species.
- Marine organisms threatened by lower oxygen levels and ocean acidification. E.g. bleaching of corals at the Great Barrier Reef.

Climate

- A rise in the mean global temperature.
- Sudden shifts in weather patterns and more extreme weather events, such as floods, storm surges and droughts.
- Climate change will vary from region to region - some areas are becoming warmer and drier and others wetter.

Hydrological cycle

- Increased temperatures and evaporation rates will cause more moisture to circulate around the hydrological cycle.
- Less winter snowfall and rainfall. River discharge patterns could change, with greater flooding in winter and drought in summer.
- As glaciers melt, water flows would result in increased sediment yield.

Arctic

- Melting permafrost releases carbon dioxide and methane. This will increase greenhouse concentration in the atmosphere, leading to further temperatures rises and melting.
- Melting Arctic (and Antarctica) ice sheets and glaciers, will cause many major coastal cities (e.g. New York) around the world to threaten from severe flooding due to sea level rises.

Energy Consumption and Demands

This is the amount of energy or power used. However, the amount of energy consumed depends on things such as lifestyle, climate, technology, availability and demand.

The demand for energy has risen due to increasing population, economic development and rising living standards. This demand has been largely met by the **burning of fossil fuels**.

There is a very close relationship between **GDP per capital** and **energy consumption**. This is due to energy being necessary for countries to become economically successful.

Energy Security

Energy security describes access to reliable and affordable sources of energy. Countries like Russia and Canada, with surplus energy, are more energy secure. Those with an energy deficit, like the USA and UK, suffer energy insecurity.

The 4 key aspects of energy security are Availability, Accessibility, Affordability and Reliability.

Affordable and competitively priced energy supply

Reliable and uninterrupted energy supply	ENERGY SECURITY	Accessible and available energy supply

Energy mix dependent on domestic rather than imported sources of energy

Having energy security is fundamental for **transportation, lighting, agriculture, domestic appliances, communication and manufacturing**.

Energy Mix

This is a combination of the various primary energy sources (those that are consumed in their raw form) used to meet energy needs in a given geographic region.

Most energy today is consumed in the form of **electricity** (secondary source). The main **primary energy sources** in the generation of this electricity include fossil fuels (oil, natural gas and coal), nuclear energy and the many sources of renewable energy (biofuel , hydro, wind, solar and etc).

In countries (such as the UK) where there **isn't enough energy domestically**, they need to **import energy** from overseas sources who are energy secured (such as Russia).

Case Studies: UK and Norway Energy Mix


United Kingdom

- Dependent on domestic coal since the 1970s. Although this has been recently declining.
- An increasing use of North Sea oil and gas after 1970s. Although expensive, this was seen as a more secure alternative to the rising price of Middle Eastern Oil.
- 'Clean coal' technology exists but lacks political & public support due to climate change concerns
- Becoming more reliant on imported energy and privatisation of its energy supply industry.
- Public concerns over using fracking (earthquakes & water pollution) and nuclear energy.

- UK aims to broaden energy mix in the future, with a greater emphasis on renewable sources (particularly offshore wind) and nuclear energy (Hinkley Point C near Bristol).
- Carbon dioxide levels have decreased from 11.5 tonnes in 1980 to 7.13 tonnes per capita in 2015.

Norway

- Norway still has huge oil and gas potential. It currently exports oil and gas to other European countries (the UK being the prominent importer).
- Norway also has huge renewable energy potential. Hydroelectric power supplies 98% of its renewable electricity energy.
- Norway has some of the best technology in the world when it comes to Deepwater drilling.
- Government restricts foreign companies from owning its primary energy sources.
- Profits from Norway's energy sector goes towards a wealth fund to support future needs.

- Norway intends to be carbon neutral by 2050.
- Carbon emissions have actually slightly increased from 11.6 tonnes in 1986 to 11.74 tonnes per capita in 2015.
- Norway has heavily invested in infrastructure that supports the use of electric cars.

Energy Players

Transnational Corporations (TNC's)	Organization of Petroleum Exporting Countries
Often state owned or part state owned companies involved in exploring, extracting, transporting, refining and producing petrochemicals. Includes Shell and BP.	A 12 member organisation that owns two thirds of the world's oil. It controls oil and gas prices by holding back reserves. Includes Saudi Arabia and Angola.

Consumers	Energy Companies
An all embracing term but the most influential consumers are transport, industry and domestic users. Largely passive when it comes to fixing energy prices.	Companies that convert the primary energy (oil, gas etc) into electricity and then distribute it. They set consumer tariffs. For example EDF and British Gas

National Governments

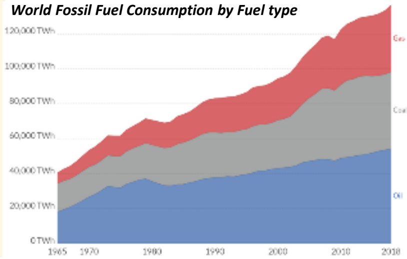
They can play a number of different roles; they are the guardians of national energy security and can influence the sourcing of energy for geopolitical reasons. For example, the UK and Norway Energy Partnership.

Fossil Fuel Demand & Mismatch

There is a mismatch between locations of conventional fossil fuel supply (oil, gas, coal) and regions where demand is the highest.

- The **growth of development** around the world has meant **global demand for energy** is increasing.
- Fossil fuels (oil, gas and coal) still **make up 86%** of the global energy mix.
- The global consumption of different energy sources has **nearly doubled since 1990**, mainly due to the rapid growth of China.
- It is estimated that by 2035, **China will be the world's largest energy importer**.
- They will have to import energy because there will be a **mismatch** between **domestic supply & demand**.

World Fossil Fuel Consumption by Fuel type



Energy Pathways

There are several major energy pathways which carry huge amounts of fossil fuels. These pathways depend on **multilateral** (between many countries) and **bilateral** (between two countries) agreements. Some countries/companies build energy pathways which avoid **transit states** (a place through which energy flows) in order to make them more secure.

Map of Nord Stream

Examples of major pathways include:

- **Nord Stream** - connects Russia to Europe via pipelines on the bed of the Baltic Sea
- **The Yamal-Europe pipeline** – runs from Russia, through Belarus and Poland and into Germany
- **Kazakhstan-China** – a 2,800km long pipeline taking crude oil to Xinjiang in China .

Threats to Energy Pathways

- Shipping lanes that carry gas and oil are prone to **piracy attacks**. For example the Strait of Malacca.
- Pipelines are vulnerable to **physical and cyber attacks** from militants, terrorist or state sponsored hackers.
- Pipelines can be damaged due to **climatic** or **environmental conditions**. E.g. Trans-Alaska Pipeline.

Unconventional Fossil Fuels

Coal, petroleum, and natural gas that have historically been economically or technically infeasible to produce. This may have been due to the geologic location of the fuel source, host rock composition, and the technology/methods necessary to actually acquire or refine it.

Tar Sands	Shale Gas	Oil Shale	Deep Water Oil
Also known as oil sands. This is a mixtures of sand, clay, water and bitumen (heavy oil).	Methane or natural gas which is held in underground sandstone and shale.	Deposits of kerogen within sedimentary rocks that haven't yet become oil.	Companies are looking into deeper ocean waters. This is more risky and expensive.

Case Study: Canadian Tar Sands

Location and Background

Canada holds the **world's largest reserves of tar sands**, with three major deposits in **Alberta**. The area is larger than England. The tar sands increase **Canada's energy security**. Regional and national governments **promote for economic purposes**.

Benefits

- Tar sands is a **relatively secure source of energy** in comparison to other sources.
- It provides a **localized economic benefit** such as jobs with huge wages.
- Some **land preservation and repair efforts** can occur simultaneously with tar sands operations.
- **Earns revenues** for provisional and national governments in the form of taxation.

Players

Nation and Regional Governments: Strongly in favour of exploiting tar sands reserves.
Oil companies: Against any rigorous environmental regulations that might reduce profits.
Indigenous Communities: Concerned about traditional lands and incidences of cancer among community. Often not receiving economic benefits.
Greenpeace: Refers to it as 'environmental disaster'.

Negatives

Tar sands oil creates **three times the greenhouse gas of conventional oil production**. Their emissions have been linked to respiratory sickness, asthma, and even cancer. Environmentally, the tar sand extract and dump **four tonnes of soil for every one barrel of oil**. This means destroying massive plots of land for small oil yield.

Alternatives to Fossil Fuels

Renewable Energy	Recyclable Energy
Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale.	Recyclable resource can be used over and over, but must first go through a process to prepare it for re-use. Can be human-driven or naturally occurring.
Biomass, Solar Power, Wind Energy, Wave and Tidal Energy, Hydroelectric Power (HEP)	**Nuclear Power, Biomass, Heat Recovery Systems, or ground source heat pump.**

Alternatives to Fossil Fuels (continued)

Renewable Energy

- x May require large areas (solar arrays, wind farms) for effective operation.
- x NIMBY (not in my back yard) issues.
- ✓ Limited to no greenhouse emissions.
- x Gas, oil and coal are less expensive options.
- x Dependent on geographical surrounding.

Recyclable Energy

- ✓ Can be used repeatedly, if managed carefully.
- x Large land area needed for biomass.
- x Largely unresolved issues of storing high level radioactive waste.
- x Risks with safety and security of nuclear energy.
- x High technological knowledge is required.

Example: The UK – The Linc Wind Farm

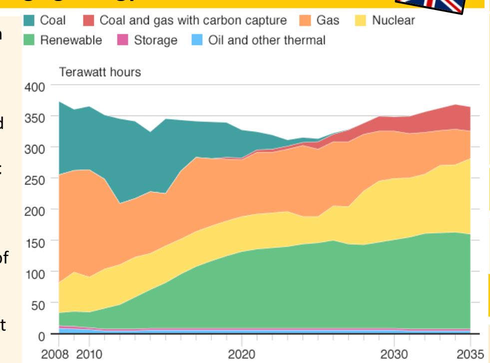
This is a 270 MW offshore wind farm 8 kilometres from Skegness in the east of England. The total cost of the project was estimated at £1 billion. The farm was completed in 2013. An additional offshore windfarm nearby at Triton Knoll, is near completion.

Example: The UK - Hinkley Point C

Aim is to provide reliable energy at an affordable cost, powering nearly six million homes for around 60 years and creating more than 25,000 jobs. The project aim is to meet the country's climate change commitments in a cost-effective way.

The UK's Changing Energy Mix

- The UK consumes less energy today than it did in 1970, despite an extra **6.5 million people**.
- The major change in the make-up of UK energy consumption is the **rapid decline in coal use**.
- The void left by the fall in coal use has been filled largely by a **rapid rise in natural gas**.
- By 2030, it expects **renewables to be the biggest source of energy** used in electricity generation, making up 40% of the overall mix.
- **Nuclear** is also set to **contribute more** by the 2020s. This is because the UK's new generation of nuclear power stations comes online.
- Overall, the UK may still be using the same amount of energy in 2030 as it was in 1970, but it will be generating it in very different ways.



Alternative Energy Source: Biofuels

Biofuels are fuels produced from organic matter (biomass). Biofuel includes bio-ethanol (from sugar beet, cane, maize and wheat), bio-diesel (from animal fat and vegetable oil) and bio-methane (from domestic and animal waster, sewage and organic waste).

CASE STUDY: Biofuels in Brazil

Brazil took the lead when it diversified its energy sources in order to combat concerns about power supply security, investing in alternative energy sources such as **hydroelectricity** & **biofuels**. Today, **45% of its energy comes from renewable sources** and approximately **90% of new passenger vehicles sold in Brazil contain flex-fuel engines**, which work using any combination of gasoline and sugarcane ethanol. This has led to a significant reduction in the country's CO_2 emissions, with **600 million tons of CO2 being avoided since the 1970s**. However, the large-scale production of biofuels has led to **large clearances of the Amazon Rainforest**.

Alternative Energy Source: Radical Technologies

Carbon Capture and Storage

- Involves 'capturing' the carbon dioxide released by the burning of fossil fuel, and burying it deep underground (i.e. disused gas reservoirs).
- Carbon capture is a very expensive process due to the complex technology involved.
- Uncertainty over whether the stored carbon will stay trapped underground or if it will slowly leak to the surface and into the atmosphere.
- Has the potential to cut global carbon emissions by 19% if financially viable.

Hydrogen Fuel Cells

- Combines hydrogen and oxygen to produce electricity, heat and water.
- A promising technology for powering buildings and electric vehicles.
- Sourcing hydrogen isn't cheap or easy.
- Is the most abundant chemical element, but does not occur naturally as a gas. e.g. Water.
- Once hydrogen can be separated easily, these cells will be able to offer a real prospect of successfully reducing carbon emissions.

Global Demand for Resources

Global demand for food, fuel and other resources globally has led to contrasting regional trends in land-use cover. This is affecting the terrestrial carbon stores with wider implications for the water cycle & soil health.

Deforestation	Grassland Conversion
Clearance of forest has occurred for the timber and land they occupy. Land is often used for grazing or for cash crops, such as palm oil.	Temperate and tropical grasslands have been heavily exploited by agriculture. Ploughing leads to a loss of carbon dioxide and moisture levels.

Urbanisation

Many ecosystems have been destroyed by rapidly growing urban population and economic activities. This particular demand is the **most disruptive impact** due to their greenhouse emissions and thirst for water.

Ocean Acidification

Ocean acidification is a **change in the chemistry (pH levels) of the world's seas**, primarily due to the **burning of fossil fuels**. This is having severe consequences for marine wildlife and ecosystems. For instance, coral reefs will have reduced calcification rates of up to 60%. A reduction could affect the **corals' ability to build faster than the skeleton is eroded**. Weaker structures are likely to be prone to **greater degrees of erosion from storms and heavy wave action**. A rise in ocean surface temperatures is also **causing widespread bleaching**.

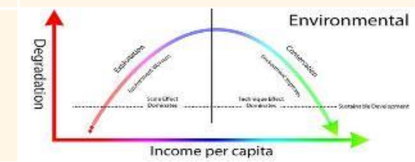
CASE STUDY: The Health of the Amazon - Droughts

The Amazon rainforest is a giant regulator. Everyday, it pumps **20 billion tonnes** of water into the atmosphere. The forests' uniform humidity lowers atmospheric pressure, allowing moisture from the Atlantic to reach the rest of the continent.

Amazon Drought in 2010

Nonetheless, since 1990 there has been **extreme drought and flooding**. In 2005 and 2010, droughts alongside **large-scale deforestation** degraded most of the forest. As a result, the declining health of the rainforest **has reduced it as a carbon store**, its ability to **sequester CO_2** and role within the **hydrological cycle**.

Implications for Human Wellbeing

	Impacts	Recovery
Forest Loss	The vast amounts of carbon released into the atmosphere has resulted in **rapid loss of biodiversity**, **habitats** and **indigenous communities**. Forests will have lost their ability to sequester CO_2 and store carbon.	• **7.6 million hectares** of forest were **lost** but **4.3 million hectares** were **gained**. • **Temperate forests** have **increased** but **tropical forests** have **declined**. • Brazil **halved** its rate of **deforestation**.
Environmental Kuznets Curve	The Kuznet Curve suggests that economic development initially leads to a deterioration in the **environment**, but after a certain **level** of economic growth, a society begins to improve its relationship with the **environment** and **levels** of **environmental** degradation reduces.	

Rising Temperatures

Rising temperatures from greenhouse gases are increasing rates of both evaporation and water vapour. As a result, this will change precipitation patterns, river regimes, the cryosphere and drainage basin stores.

Declining Ocean Health

Acidification and **bleaching** have resulted in changes to marine food webs. This will effect people/countries who; depend on **fishing** for jobs and/or a source of food, the **tourism industry** based around coral reefs. Rising sea levels will increase costs for countries having to strengthen their **coastal defences**.

CASE STUDY: Ocean Health - The Arctic

The Arctic plays a key role in regulating evaporation and precipitation. Recently, temperatures there have risen **twice as fast as the global average**. This has led to a **rapid loss of sea ice** and therefore a **decline in the albedo effect** – which will increases temperatures even further. However, due to longer growing season, **carbon uptake has increased** and **navigation through the North-West passage** during summer is now possible.

Uncertainty of Global projection

Due to the ever increasing global consumption of energy, greenhouse gas emissions are expected to rise. Some climate models project that surface temperatures will **continue to rise 2-6°C by the end of this century**. Some regions such as the Arctic will exceed global average temperatures. Nonetheless, these projected future scenarios have a range of physical and human uncertainties.

Physical Factors

- Oceans and forests function as carbon sinks and store heat energy. As a result, **oceans take longer to respond to atmospheric changes** and so they will continue to affect the global climate for a long time if/when human emissions slow.
- **Forest cover increasing** will make it a more efficient carbon sink; in HIC countries there is evidence that more trees are being planted.

Human Factors

- **Economic growth isn't always steady**. i.e. the 2008 financial crash affected rates of emission.
- **Energy consumption is still growing**, however **renewable energy is becoming more available**.
- Countries could **embrace or reject the use of green technology**, affecting emissions of GHGs.
- There could be **technologies in the future** which would better help to combat CO_2 emissions.

Adaption strategies for a Changed Climate

Adaptation strategies are ways to live with the impacts of climate change.

	Positives	Negatives
Water conservation	Less ground abstraction and an increase use of grey water.	May not meet water demands and therefore will need enforcement.
Land-use planning	Restrictions on building on floodplains and low-lying coastlines.	Needs strong governance and not realistic for large urban areas at risk. e.g. Dhaka.
Flood-risk management	Reduced deforestation and changes to urban designs to reduce flood risk.	Requires an increased investment, maintenance and possibly compensation.

Adaption strategies for a Changed Climate

Mitigation aims to rebalance the carbon cycle and reduce the impact of climate change.

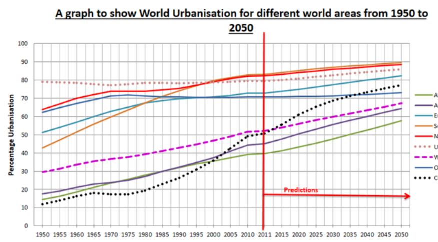
Carbon taxation	Unpopular with industry and environmental groups, it was 'frozen' in 2015 by the UK government. It aimed to set a minimum price for the CO^2 emitted by companies.
Renewable switching	These provide intermittent electricity and not the continuous power that fossil fuels provide. National governments (e.g. Sweden) are now investing and supporting their use.
Energy efficiency	Aims at reducing energy consumption by constructing products/places with energy-saving improvements. Evident with energy efficient boilers, LED lighting, insulation & batteries.

Unit 2c: Contemporary Urban Environments

AQA

Global patterns of urbanisation

In 1945 less than one third of the world's population lived in urban areas. By 2008, more people lived in urban areas than rural areas. Urbanisation in HIC's peaked in the 1900's there has since been rapid **suburbanisation causing urban growth.** Rates of urban growth are slowing down however, in all continents and globally. This means that urban areas, whilst still growing, are doing so at a slower pace



Urbanisation issues

Cities in 9/10 countries have higher levels of inquietly than national average.

Economic inequality - Occurs in access to services, open land, education and to employment =poverty

Social inequality = Housing is a major cause of urban exclusion

Cultural diversity = This links both social and economic issues

Economic - migrants tend to work in labour where wages are lower and could led to a lack of jobs for locals

Housing = Ethnic minorities are less successful in securing mortgages and can led to residential succession

Education = variation in attainment (ethnic minorities more likely to attend university)

Health = poor quality environment impacts health

Religion = conflict due to misunderstanding and festivals

Entertainment = 75% of Europeans consider sport as a means of integration.

Urban Sustainable Development

Ecological footprint – Amount of land needed to produce everything consumed. This will be impacted by wealth, public transport availability and size of the city.

Liveability – combination of factors that determine a community's quality of life.

Natural –	Physical –	Social –	Economic –
-increase urban space -improve waste disposal	-improve quality of housing	-Improve transport -improve education	-improve economic opportunities.

Curitiba – Brazil – although has mass poverty considered to be sustainable

Urban Policy

Urban policy = strategies chosen by the local or central government to manage the development of urban areas and reduce urban problems.

Year	Policy name	Explanation	Example
1981	Urban development corporations	Re-develop deindustrialised areas	London Docklands
1981	Enterprise Zones	Small area of land opened to attract high-tech businesses	Metro Centre Gateshead
1997	Single regeneration budget	A coherent scheme that local councils had to bid for	Oueburn Valley, Newcastle
2010	Local enterprise partnership	Determine local priorities and support economic growth	Birmingham
2011	Localism act and tax increment	City leaders can be given powers to set own local policies	London

Urban Air Quality

Urban areas have large amounts of particles (10-40micrograms compared to >10 in rural areas) this is due to industry

Smog = mixture of smoke and fog occurs when smoke particles and sulphur dioxide from burning coal mix with fog.

Airpocalypse (Beijing) - 2013 smog was 35x stronger than WHO limit

Methods to reduce urban air pollution:

- Congestion charging
- Vehicle restrictions
- public transport improvements
- Alternative fuels
- Pedestriastion
- legislation

Urban Environmental Issues

Water Pollution – Common in urban areas due to industry and large amounts of wastewater (sewage) which can cause damage to ecosystems.

Air pollution – Air quality is a lot poorer due to industry and accelerated due to urban microclimate

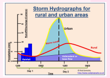
Dereliction – When economic activity declines buildings become run down.

Detroit – 1970 oil crisis saw industry decline and became 'rust belt' with x2 national unemployment rate. Air and water pollution have improved

Urban Drainage

Infiltration is low due to impermeable surface = replenishment of groundwater is slow.

Runoff is channelled through drains to transport water out of the area quickly.

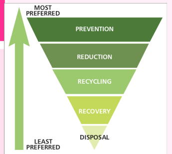


Sustainable Drainage System (SuDS) – A realistic, environmentally friendly replica of natural drainage system. For example: permeable surfaces, infiltration trenches, green-roofs, rainwater storage etc.

Eg: Lamb Drove, Cambourne

River restoration – removing all hard engineering to restore natural river.

River Skerne, Darlington – between 1850 and 1945 the river was straightened but in 1995 a project reconstructed meanders (soft engineering). This helped reduce flood risk and attract tourists.



Urban Microclimate

Urban microclimate = an area where the climate differs from the surrounding area

Characteristics:
- *30% lower wind speed*
- *5-10% more precipitation*
- *smog*
- *2-3 weeks fewer frost*
- *Low relative humidity*
- *5-10% more cloud*
- *1-3°c warmer at night*
- *Higher pollution*

Urban heat island – urban area is significantly warmer than surrounding rural area.

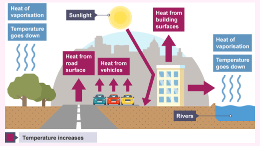
-Urban areas have a lower albedo

-Less heat energy is lost in evaporation as water goes down drains

-buildings leak heat poor through insulation

Urban precipitation – The ground is heated through solar radiation

The air warms, rises, cools, condenses and falls as rainfall as it attaches to condensation nuclei.



Urban wind – Generally wind is lower due to friction however there are two effects; urban canyons (funnel of wind between buildings) and venturi effect (air is forced above and around buildings. When it hits the floor violent gusts form).

Urban Waste

1/5 of all global waste is likely to have been produced in urban areas costing $205 billion each year.

Types of waste: domestic/ municipal/commercial/ institutional

Disposing of waste:

- Landfill = waste is placed in disused mines, quarries or sites
- Incineration = Waste is burnt an can be used to produce energy
- Recycling = Waste is reproduced into new products
- Submergence = dumping waste in oceans

Global waste trade: some waste is sent from HIC's to LIC's this is usually electrical or chemical waste that is dangerous.

New Urban Landscapes

Urban areas are constantly changing and adapting there are many new landscapes forming:

- *Town centre mixed development* – any urban development that blends residential, commercial, cultural and infrastructure
- *Cultural and heritage quarters* = An area that keeps cultural acidity through cultural production
- *Fortress Landscape* – urban development constructed with safety in mind
- *Edge cities* - Suburbs that have developed into urban centres in own right.

Urbanisation

- **Urban growth –** The increase in total population of town or city
- **Urban expansion –** The increase in size geographical footprint of a city

Some cities may experience growth and expansion but if this growth is not matched by population increases in rural area, urbanisation is not occurring.

Importance of urban centres – political power/ social and cultural sites/ economic production/ exchange of ideas/ migration centres/ highly skilled jobs/ shopping

World city

World city = How well connected they are to the rest of the world and the global economy = homogenisation

Transport hubs – good access by rail and air
- developed road

Information – state of the art communication

Demographics – large population
- Ethnic diverse with high tolerance
- high proportion of educated population

Culture – centre of excellence of arts
- rich heritage

Finance and trade – major hubs of international banking
- headquarters of multinational companies

Governance – national seat of government

World cities have emerged for many reasons, technological changes, colonial influences, ports and trading centres etc.

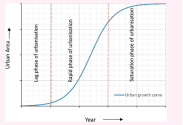
Forms of urbanisation

Urbanisation – The increase in proportion of population living urban centres

Suburbanisation – The decentralisation of people, employment and services to the edge of an urban areas

Counterurbanisation – People move out the city back to surrounding rural settlements.

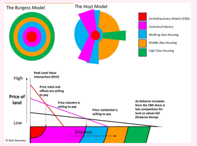
Resurgence – population moves back from rural to urban areas.



Urban forms

Urban forms = The physical characteristics that make up built areas including shape, density and configuration of settlements.

Bid rent theory = The price and demand for real estate changes as the distance from the CBD increases. This is because central areas tend to have better infrastructure.



Case studies of two contrasting urban environments

MUMBAI

Total population -	20 million

World city – Mumbai is India's largest city. It is the commercial capital home to India's stock exchange. As well as hosting the headquarters of trans-national corporations such as Cadbury India, Volkswagen, and Tata steel. Mumbai airport carried 36 million passengers to 45 different countries in 2015.

Urbanisation - The growth of the city has mainly been historic; it is still growing but a lot of this change took place between 1971 and 1991. This has mainly increased due to rural to urban migration (push factors = new farming techniques in India has meant that there are fewer jobs in farming, poor standard of housing and pull factors = cheaper travel costs, variety of jobs, better access to education and healthcare) and natural increase.

Positive impacts –
- Large informal sector provides opportunities
- Shanty towns help to housing shortage
- Better healthcare

Negative impacts –
- 55% of city live below poverty line
- 1/3 population been a victim of crim
- 62% of population live In slums

Suburbanisation – Mainly occurred in1970's, towns and villages have been swallowed up by Mumbai in the process of suburbanisation. In the last decade, Thane, Vashi and Belapur have become extended suburbs despite being planned as individual towns. The biggest growth occurred along the train routes.

Urban Change - In 1854 the first Indian cotton mill was opened after the British had colonised India.
Decentralisation: Large cities like Mumbai need efficient mass transport systems so commuters can get into work quickly. This also led to more people moving to the suburbs (suburbanisation).

Regeneration - Bhendi Bazaar – once was an area of mixed chawls and 1,250 shops and stalls. It is estimated that 20,000 people lived there. The chawls were old and overcrowded. There was no proper waste disposal system and water was only supplied for a few hours each day.
2010 plan = demolish 250 buildings and replace them with 17 high rise tower blocks. The project including:
- use of natural light and ventilation
- rainwater harvesting
- solar panels
- sewage treatment

The Society for the Promotion of Area Resource Centres, better known as SPARC, is an NGO that supports the efforts of local people to get better housing for their many members. Instead of demolition it teaches people how to improve their home.

Urban climate – Mumbai is 5C-7C warmer than in the surrounding rural areas on summer nights. In 2016, Mumbai was ranked the 63th most polluted city in the world. Mumbai often experiences heavy smog around Diwali which is x20 more than WHO limit.

Urban waste – Mumbai generates about 10,000 tonnes of waste each day. This has risen by 105% from 1999 to 2016. Only 95% of Mumbai have a rubbish collection. The rest of the city is expected to dispose of waste in a correct way. Of the 9,400 tonnes of rubbish that Mumbai sends daily to its dumping grounds , 73% comprises food, vegetable and fruit waste. 8% of all waste in Mumbai is recycled (this is often completed by those who live In the slums).

Sustainable development – Mumbai is currently one of the least sustainable cities in the world due to its reliance on fossil fuels, population rise and lack of sustainable transport.
Aim:
- An SPV (special project vehicle) - an elevated sub-urban corridor project. This will transport 4 million passengers as well as a metro system transporting 9 million.
- Urban Farming: The Navi Mumbai Eco-City project – a carbon neutral city which is a Bottom up approach to development using opinions of locals

LONDON

Total population	18.9 million	BME (Black or ethnic minority)	41%

World city - London is a global city as it is home to some of the world's top universities. There are around 300 languages spoken. 37% of the population was born outside the UK. There are endless opportunities for entertainment such as the West End. It has 3 international airports. Houses of Parliament and Canary Warf.

Urbanisation - Peaked in mid 1900's (70% of population lived in cities). The vast majority of the recent growth in London has come from net international migration. London added 690,000 residents between 2001 and 2010. This pattern has become more prevalent since European Union enlargement, when Eastern Europeans began moving in much larger numbers to London.

Positive impacts –
- Agglomeration effect = easier to provide services as people live closer together

Negative impacts –
- 28% of Londoners are in poverty (10x higher) – this is highest in black or ethnic minority (38%)
- Violence and sexual offences x2 more prevalent

Suburbanisation –This mainly occurred in the 1960s and 70's where car ownership encouraged people to migrate. As well as this a small 'white flight' occurred as thee wealthy white moved away from inner city areas that were attracting BME populations (Brent has 69% BME population).

Urban Change – De-industrialision: Collapse of manufacturing began in 1950's due to; protectionism, trade unions, high exchange rate, lack of competitiveness = 1978 = 6.7 million manufacturing workers in UK → 2.7million in 2017.
Decentralisation: occurred in 60's and 70's where jobs lost were masculine and replaced by women bringing a 'new set of gender roles' (Doreen Massey, 1994).
Gentrification: Areas such as Notting Hill have been gentrified from slums to some of the most expensive areas

Regeneration - Stratford = one of the most deprived communities in the country, where unemployment was high and levels of health were poor. There was a lack of infrastructure and the environmental quality was poor. The 2012 London Olympics bid was partly successful on the understanding that Stratford would be used during the games and regenerated for local people to use after the competitors had left.
Aims included:
- By 2030, more than 10,000 new homes will have been built in the park
- A new academy has been built, which is used to educate around 2,000 pupils between the ages of 3-18.
- over 20,000 jobs could be created by 2030, bringing more than £5 billion into the area.
- Sustainable - walking and cycling routes, the provision of public transport, the water-efficient design of homes and the protection of green spaces and natural habitats.

Urban climate – The highest temperatures are found in the city centre which are on average 5°c warmer. A London skyscraper dubbed the "Walkie-Talkie" was blamed for reflecting light which melted parts of a car parked on a nearby street.

Urban waste – London produces 7m tonnes of waste from homes, public buildings and businesses each year. Only 52% is currently recycled and the capacity of landfills accepting London's waste is expected to run out by 2026 and London's waste bill is now in in excess of £2bn a year and rising.
Aims:
- Circular London programme to create the conditions required to allow a circular economy
- London will be a zero waste city. By 2026 no biodegradable or recyclable waste will be sent to landfill and by 2030 65% of London's municipal waste will be recycled.

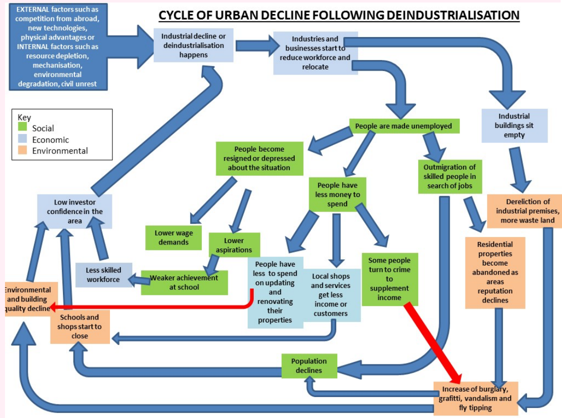
Sustainable development -
London's ecological footprint is currently 120x greater than its actual size.
- London as an eco-district = Headquarters of Bloomberg's have been designed in keeping with the local architect and includes air source heat pumps, green roof etc
- BedZed London = 82 affordable houses is a carbon-neutral development site

Megacity

- **Millionaire city** – A city with more than 1 million people
  - Birmingham – 1.086 million
- **Megacity –** A city with at least 10 million people
  - New York = 18 million – 1st megacity
  - There are now 26 megacities across the world
- **Metacity –** A city with more than 20 million people
  - Tokyo = 38 million

Urban Change

Urban change = any change can be positive or negative eg: industrial revolution
Urban decline = the deteriation of the inner city often caused by a lack of investment and maintenance
Deindustrialisation = Long term decline of a country's manufacturing
Decentralisation – Movement of shops and services away from urban centres.



Gentrification - Gentrification is the process by which wealthier (mostly middle-income) people move into, renovate, and restore housing and sometimes businesses in inner cities or other deteriorated areas formerly home to poorer people.

Post-modern

- Pre-industrial city = Bath
- Modern city = Birmingham
- Public Transport Orientated = Hong Kong
- African City = Nairobi
- Socialist city = Prague
- Post-industrial city = A world that emphasizes diversity.

Urban structure = chaotic with high-tech
Urban architecture = Unusual mix of styles
Urban government = international capital
Urban economy = quaternary dominated
Culture = high levels of polarisation

Unit 1, Section A, Topic 1
Water & carbon cycles

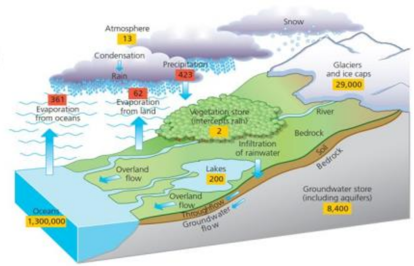
1.1 Systems

The interrelationship between living and non-living components within an environment

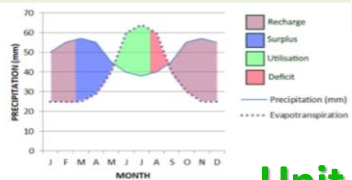
Input	Material or energy moving into the system from outside	e.g. precipitation
Output	Material or energy moving from the system to outside	e.g. evaporation
Energy	Power or driving force	e.g. heat
Stores / components	The individual elements or parts of a system	e.g. trees
Flows / transfers	The links or relationships between components	e.g. infiltration
Open system	Linked to other systems	e.g. drainage basin
Closed System	Self contained	e.g. global water cycle

1.2 The global water cycle

- Describes the Earth's stores and transfers of water
- The vast majority of water is stored in oceans as salt water
- Most fresh water is stored as ice or groundwater
- Water is uneven distributed around the world



The **soil water budget** describes the changes in soil water over a year



Water is stored within 4 major systems:

- **Lithosphere** (land)
- **Hydrosphere** (liquid water)
- **Cryosphere** (frozen water)
- **Atmosphere** (air)

1.3 Changes in the water cycle

Precipitation	Transfer of water from atmosphere to ground in the form of rain, snow or hail
Evaporation	Transfer of water from a liquid to gas
Condensation	Transfer of water from a gas to liquid
Sublimation	Transfer from a solid to gas or visa versa
Interception	Preventing water from reaching the ground
Overland flow	Transfer of water over the surface
Infiltration	Transfer of water from the surface to the soil
Throughflow	Water flowing through soil towards a river
Percolation	Water soaking into rocks
Groundwater flow	Very slow transfer of water through rocks

1.5 The water balance

- Helps to understand the characteristics of **drainage basins**

Drainage basin	An area of land that is drained by a river and its tributaries

P = O + E +/- S

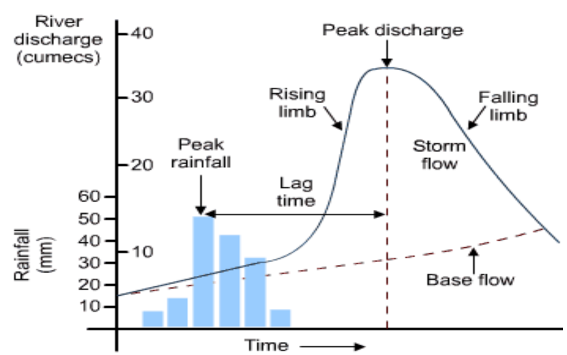
Where P = precipitation, O = total runoff, E = evapotranspiration, S = storage

- Runoff enables comparisons to be made between drainage basins
- The geology, soil moisture and land use all influence runoff
- Higher percentages of runoff are mainly linked to **saturated soils** and **urbanisation**

1.7 Factors influencing change in the water cycle

Physical	Human
Drought Flooding Seasonal variations	Land use change Farming practices Water abstraction

1.6 The flood hydrograph



Lag time	The difference between the peak rainfall and peak discharge
Limb	Shows the change in river discharge

- Shows the response of a river following a storm event

Discharge	The volume of water flowing down a river
Velocity	The speed of the river's flow

- The shape of a flood hydrograph reflects the characteristics of the drainage basin

Flashy	Low
Short lag time	Large lag time
High peak	Low peak
Small basins	Large basins
Rapid water transfer	Slower water transfer
Impermeable rocks	Permeable rocks
Steep slopes	Gentle slopes
Saturated soils	Dry soils
Urbanisation	Forests
Heavy rainfall	Light rain

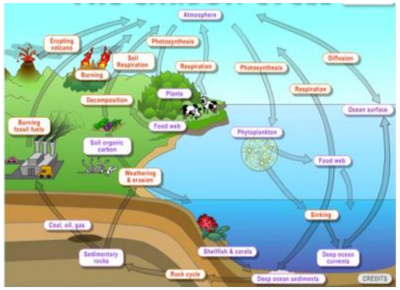
1.17 Case study: River catchment

❑ Location	❑ Relief	❑ Geology	❑ Land use	❑ Climate	❑ Recent developments influencing the water cycle
❑ Stores	❑ Transfers	❑ Hydrograph	❑ Water balance	❑ Human activity	

1.8 The global carbon cycle

- Vital for all life on Earth
- Made up of stores and transfers

Carbon sink	When a store that absorbs more carbon than it releases
Carbon source	Releases more carbon than it absorbs



1.9 Transfers in the carbon cycle

- Can also be at a local level e.g. a tree

Photosynthesis	Where plants use light from the sun to convert CO_2 and water into carbohydrates
Decomposition	When living organisms die and break down carbon is returned as CO_2 to the atmosphere.
Combustion	When organic matter is burnt releasing CO_2 from stores
Carbon sequestration	The transfer of carbon from the atmosphere to plants, soils, rocks and oceans

1.10 Factors influencing change in the carbon cycle

1.10 Physical	1.11 Human
Natural climate change	Urbanisation
Glacial conditions	Deforestation
Interglacial conditions	Burning fossil fuels
Wild fires	Changing land use
Volcanic activity	Changing farming practices

1.12 The carbon budget

- Describes the amount of carbon stored and transferred within the carbon cycle
- Most carbon is stored in the Earth's crust
- Photosynthesis is the major carbon transfer
- Important for land, oceans and the atmosphere

1.13.1 The links between water and carbon cycles

- There are important links between the two cycles
- The ability of water to store and transfer water is key

1.13.2 Links to climate change

- Feedback loops have significant impacts on climate change

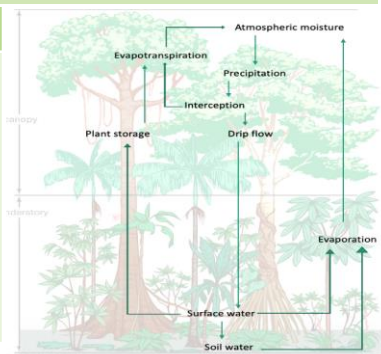
Water cycle feedback loop	• Absorption of heat from the sun warms oceans • Reducing polar ice • Ice reflects radiation • Less ice = more heat is absorbed • Creating a **positive feedback loop** • Affecting transfers between stores
Carbon cycle feedback loop	• Warmer temperatures in polar regions have two opposite effects: 1. An extended plant growing season 2. Melting permafrost
Water/carbon cycle feedback loop	• Phytoplankton promote the formation of clouds over the ocean • Warmer temperatures increase the population of phytoplankton • Increasing cloud cover • Leading to global cooling • Creating a **negative feedback loop**

1.15 Tropical rainforests: the water cycle

- Have a distinctive water cycle as a result of their high levels of precipitation, extensive canopy and plant growth

Impacts of deforestation

- Evapotranspiration is reduced
- Increased overland flow
- Increased soil erosion
- Very little interception
- Little evaporation
- Little transpiration
- Increased runoff
- Risk of flooding
- Reduced atmospheric humidity
- Reduced rainfall



1.14 Mitigating the impacts of climate change

- Human intervention in carbon transfers can mitigate the impacts of climate change

Modifying industrial combustion	Modifying deforestation
• Use carbon capture and storage technology • Store CO_2 • Reduce global CO_2 emissions by 19%	• FSC timber certification • Carbon payments to offset carbon emissions • Selective management approach to logging
Modifying land use	**Modifying photosynthesis**
• Carbon farming	• Plantation forests

Political initiatives: The Paris Agreement

- Adopted in 2015
- 195 countries
- Sets out a global action plan to limit global temperature increase
- Focus on reducing carbon emissions

1.15 Tropical rainforests: the carbon cycle

- Photosynthesis is enhanced by the lush vegetation
- Reduces atmospheric CO_2
- Huge carbon stores
- Important carbon sinks

Impacts of deforestation	Reducing the impacts
• Photosynthesis ceases • No longer a carbon sink • Rain washes ash into the soil increasing the carbon content • Low respiration • Increased carbon in runoff	• Replacing rainforest • Afforestation • Strict logging regulations • Restrictions on fires to clear land

1.16 Case study: Tropical Rainforest

❑ Location	❑ Climate	❑ Geology	❑ Land use	❑ Recent developments influencing the water cycle and carbon cycles	❑ Local impacts
❑ Stores	❑ Transfers	❑ Human activity	❑ Sustainable management		❑ Global impacts