The Carbon cycle and Energy insecurity EQ1: How does the carbon cycle operate to maintain planetary health?

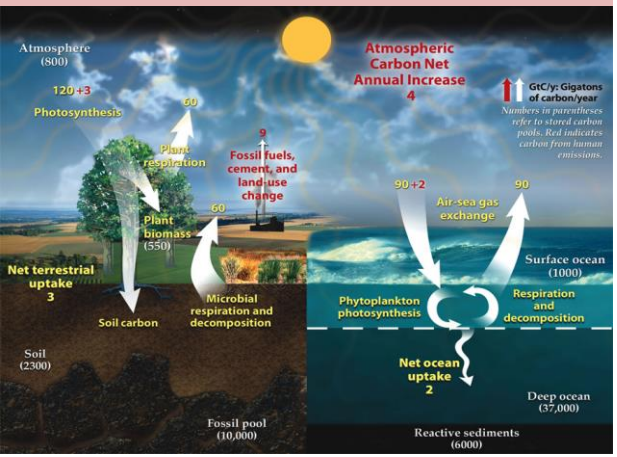
Overview: it is important to understand how water circulates at a global level and how the availability of water fluctuates over time and space. Water is vital to human survival and yet **water insecurity** is increasing and so too the likelihood of water wars.

The Carbon cycle

Key Concept – The Carbon cycle
The Carbon cycle is a closed system: it does not have any external inputs or outputs. So the total amount of carbon is constant and finite.

•**Stores** – reservoirs where carbon is held.
•**Fluxes** – the flows which move carbon between stores from one sphere to another
•**Processes** – the physical mechanisms that drive the fluxes and stores,

Carbon stores function as sources (adding carbon to the atmosphere) and sinks (removing carbon from the atmosphere).



Carbon stores
These includes:
• the atmosphere: as gases such as Carbon Dioxide and Methane.
•The hydrosphere: dissolved carbon dioxide
• the lithosphere: carbonates in limestone and fossil fuels
•The biosphere: living and dead organisms

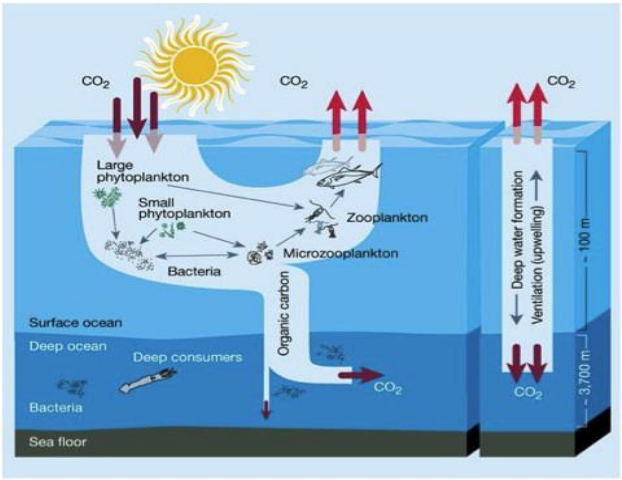
The amount of carbon dioxide in the atmosphere is added to by the burning of fossil fuels and by respiration of plants and animals. The amount is reduced by precipitation and photosynthesis.

Geological Carbon
Carbon is locked in terrestrial stores as part of the long-term geological cycle. Organic matter is buried in deep sediments and turned into fossil fuels. Carbon has also been trapped in sedimentary rocks such as limestone and chalk. The reservoir turnover (the rate at which carbon enters and leaves a store) is very long here and can last millions of years.

Volcanic outgassing can release this carbon into the atmosphere as well as the chemical weathering of rocks.

Sequestration

Key Concept – sequestering
This is a the movement of carbon into carbon stores. It has the effect of lowering the amount carbon dioxide in the atmosphere. The main process responsible is photosynthesis by plants and phytoplankton at the sea surface.



Oceanic sequestering
Shellfish rely on carbon for the shells but also release it back into the oceans. Movement of carbon within the oceans is controlled:
•Vertically – by carbon cycle pumps. There are 3 pumps and between they deliver carbon dioxide to the sea floor and to the ocean surface for release into the atmosphere.
•Horizontally – by the thermohaline circulation. This is a global mechanism involving surface and deep ocean currents driven by differences in temperature and salinity. Surface waters that lose carbon to the atmosphere gain it again in the deep oceans (similar to an escalator conveyor belt).

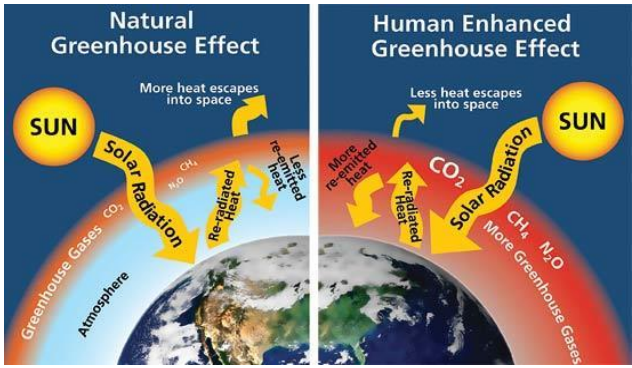
Terrestrial sequestering
Primary producers sequester carbon from the atmosphere during photosynthesis and these with consumers release it during respiration. Terrestrial sequestering is common world wide but the rate and storage capacity depends on the type of ecosystem. Storage is in trees and soils with some trees living for 100s of years meaning the carbon is locked in the biosphere for a long time. The most productive ecosystem is the tropical rainforest but fluxes can vary seasonally and diurnally.

Biological carbon
Biological carbon is mainly stored as dead organic matter in soils (20-30% of global carbon). The biological carbon that is not stores is returned to the atmosphere by biological weathering over a period of years. Since all the plants are made of carbon, any plant loss to the ground (leaf litter) means a transfer of carbon to the soil.

Carbon balance and human activity

A balanced carbon cycle is important for maintaining other systems on earth. Through it's control of carbon in the atmosphere it plays an important role regulating atmospheric temperatures and climate. This in term impacts on the hydrological cycle.

An increase in carbon impacts the greenhouse effect:



The earth's climate is driven by incoming short wave radiation. Approximately 31% is reflected back into space by the atmosphere. Nearly half of the remaining 69% is absorbed at the earth's surface, especially by the oceans, while the other half is radiated into space as long wave radiation. A large proportion of this long wave radiation is deflected back to the earth's surface by clouds and greenhouse gases, however. It is the trapping of longwave radiation that creates the natural greenhouse effect.
As more carbon is trapped global temperatures rise.

Soil health (the amount of carbon soil can store) plays an important role in regulating the atmospheric composition of carbon and the soils ability to retain water. This in turn will enhance ecosystem productivity and how much carbon is sequestered into plants. A positive multiplier effect.

Burning fossil fuels releases carbon into the atmosphere that has been stored for millions of years. Fossil fuels have been burnt at an increasing rate since the Industrial revolution and continue today to be the primary source of energy. Although this would naturally have come the surface eventually through outgassing human intervention has changed the balance and speeded up this flux. Around ½ of the extra emissions since 1750 have stayed in the atmosphere and the rest stored in soils, ecosystems and oceans. The changes in balance is causing:
•Rising global temperatures and rising sea level
•Increased evaporation causing droughts and increased precipitation
•Challenging ecosystem services and biodiversity
•Marine acidification.