Carbon capture and sequestration (CCS) technologies

Carbon capture and storage (CCS) is a technology that can capture up to 90 per cent of CO_2 emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing the carbon dioxide from entering the atmosphere.

The CCS chain consists of three parts (see Figure 1.58):

- **Capturing** the CO_2: Capture technologies allow the separation of CO_2 from gases produced in electricity generation and industrial processes by one of three methods: pre-combustion capture, post-combustion capture and oxy-fuel combustion.

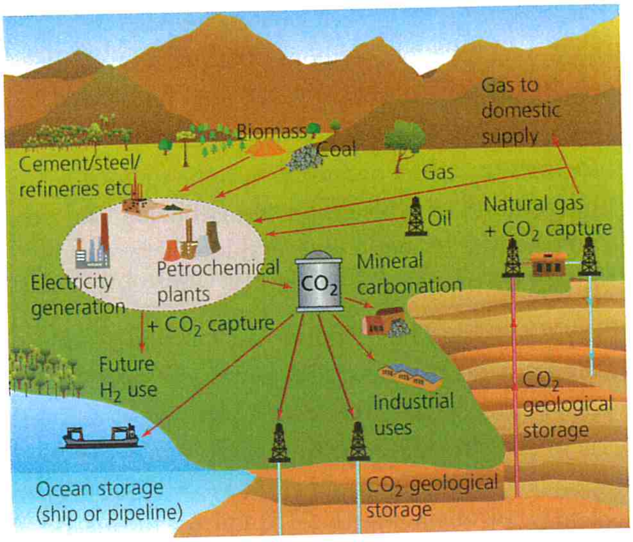

Figure 1.58 Possible CCS systems

Source: IPCC

Boundary Dam CCS plant

An example of CCS in action is at the 110-megawatt coal power and CCS plant in Saskatchewan, called Boundary Dam, built by the provincial utility SaskPower. It is a coal-fired power station complex that has been retrofitted to capture 90 per cent of its CO_2 output (approximately 1 million tonnes per year). The CO_2 will eventually be piped 66 km to the Weyburn Oil Unit and injected into an oil-bearing formation at 1,500 m depth. This will add pressure to the oil-bearing rock and so help push more oil out of the ground, a process called enhanced oil recovery (EOR). Until that is ready it will be injected into local salt formations. The capture process was started in October 2014 and CO_2 injection started in April 2015.

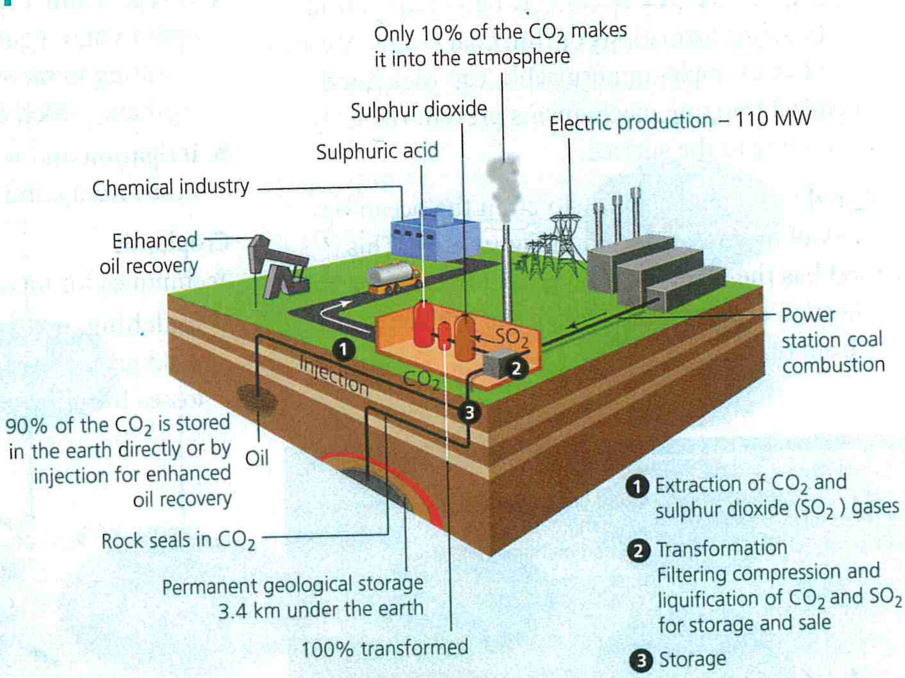

Figure 1.59 Carbon capture and storage at Boundary Dam power station, Canada

Source: SaskPower

CCS imposes big costs and energy penalties: the Boundary Dam plant's CCS unit cost $800 million to build and consumes 21 per cent of the coal plant's power output in order to scrub out the carbon dioxide and compress it into a liquid for burial. It is hoped that this extra cost will be offset by the extra oil recovered from the Weyburn oil field.

- **Transporting** the CO_2 by pipeline or by ship to the storage location: Millions of tonnes of CO_2 are already transported annually for commercial purposes by road tanker, ship and pipelines.
- **Storing** the carbon dioxide emissions securely underground in depleted oil and gas fields, and deep saline aquifer formations several kilometres below the surface or the deep ocean.

CCS systems could be used to extract a greater percentage of oil and gas out of existing reservoirs by the CO_2 being injected under such pressure as to force the oil or gas out. Although this would partly pay for the CCS technology, it would also enhance the original problem by producing more fossil fuel for burning. When CO_2 is stored in deep geological formations it is known as **geo-sequestration** (see Figure 1.60. CO_2 is converted into a high pressure liquid-like form known as 'supercritical CO_2' which behaves like a runny liquid. This supercritical CO_2 is injected directly into sedimentary rocks. The rocks may be in old oil fields, gas fields, saline formations or thin coal seams. Various physical (for example, impermeable 'cap rock') and geochemical trapping mechanisms prevent the CO_2 from escaping to the surface.

Captured CO_2 could also be stored in the ocean by a variety of means, as shown in Figure 1.61. This method has the main disadvantage of the CO_2 causing acidification of the oceans and all the problems that arise from that.

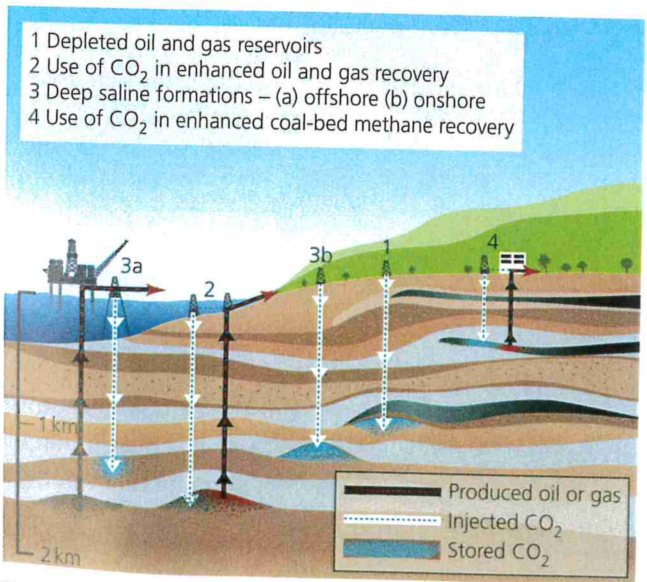

Figure 1.60 Methods for storing CO_2 in deep underground geological formations

Source: IPCC

Changing rural land use

Carbon stores can be improved by ensuring that carbon inputs to the soil are greater than carbon losses from it. There are a variety of different strategies depending on land use, soil properties, climate and land area.

Grasslands

These offer a global greenhouse gas mitigation potential of 810 million tonnes of CO_2 (in the period up to 2030), almost all of which would be sequestered in the soil. Soil carbon storage in grasslands can be improved by:

- avoidance of **overstocking** of grazing animals
- **adding manures and fertilisers** that have a direct impact on **soil organic carbon (SOC)** levels through the added organic material. There are also the indirect benefits of increasing plant productivity and stimulating soil biodiversity (for example, with earthworms that help degrade and mix the organic material)
- **revegetation**, especially using improved pasture species and legumes, can increase productivity, resulting in more plant litter and underground biomass, which can add to the SOC stock
- **irrigation** and water management can improve plant productivity and the production of SOM.

Croplands

Techniques for increasing SOC include the following:

- **mulching**, which can add organic matter. If crop residues are used, mulching also prevents carbon losses from the system

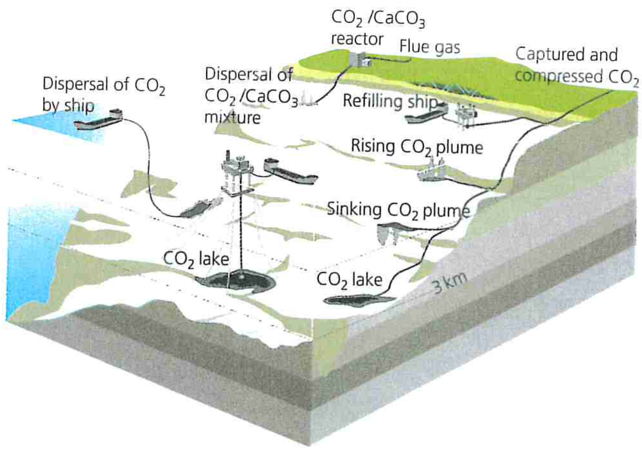

Figure 1.61 Methods of ocean storage

Source: IPCC

- **reduced or no tillage** (ploughing and harrowing) avoids the accelerated decomposition of organic matter and depletion of soil carbon that can otherwise occur. Reduced tillage also prevents the break-up of soil aggregates that protect carbon
- some use of **animal manure** or chemical fertilisers, which can increase plant productivity and thus SOC
- **rotations of cash crops** with pasture or the use of cover crops and green manures, which have the potential to increase biomass returned to the soil
- using **improved crop varieties** to increase productivity above and below ground, as well as increasing crop residues, thereby enhancing SOC.

Forests and tree crops

Forests are able to reduce CO_2 emissions to the atmosphere by storing large stocks of carbon both above and below ground.

- **Protection** of existing forests will preserve current soil carbon stocks.
- **Reforesting** degraded lands and increasing tree density in degraded forests increase biomass density and therefore carbon density, above and below ground.
- **Trees in croplands** (silviculture) and orchards can store carbon above and below ground. CO_2 emissions can be reduced if they are grown as a renewable source of fuel.

It is important to note that many of these mitigation schemes have different and unwanted side effects.

Improved aviation practices

According to the Air Transport Action Group, in 2019 the global aviation industry carried 4.5 billion passengers, producing 915 million tonnes of CO_2. Although the industry has made major strides in reducing its production of CO_2 (for example, the Airbus A380 and the Boeing 787 both use less than three litres of fuel per 100 passenger km), the EU Directorate General for Climate Action state that in 2020 the global emissions of CO_2 will be 70 per cent more than in 2005 and could be a further 300 per cent more by 2050.

The ways in which the aviation industry could reduce their emissions are shown in Figure 1.62. These must be treated with caution because many of them are still at the aspirational or theoretical stage.

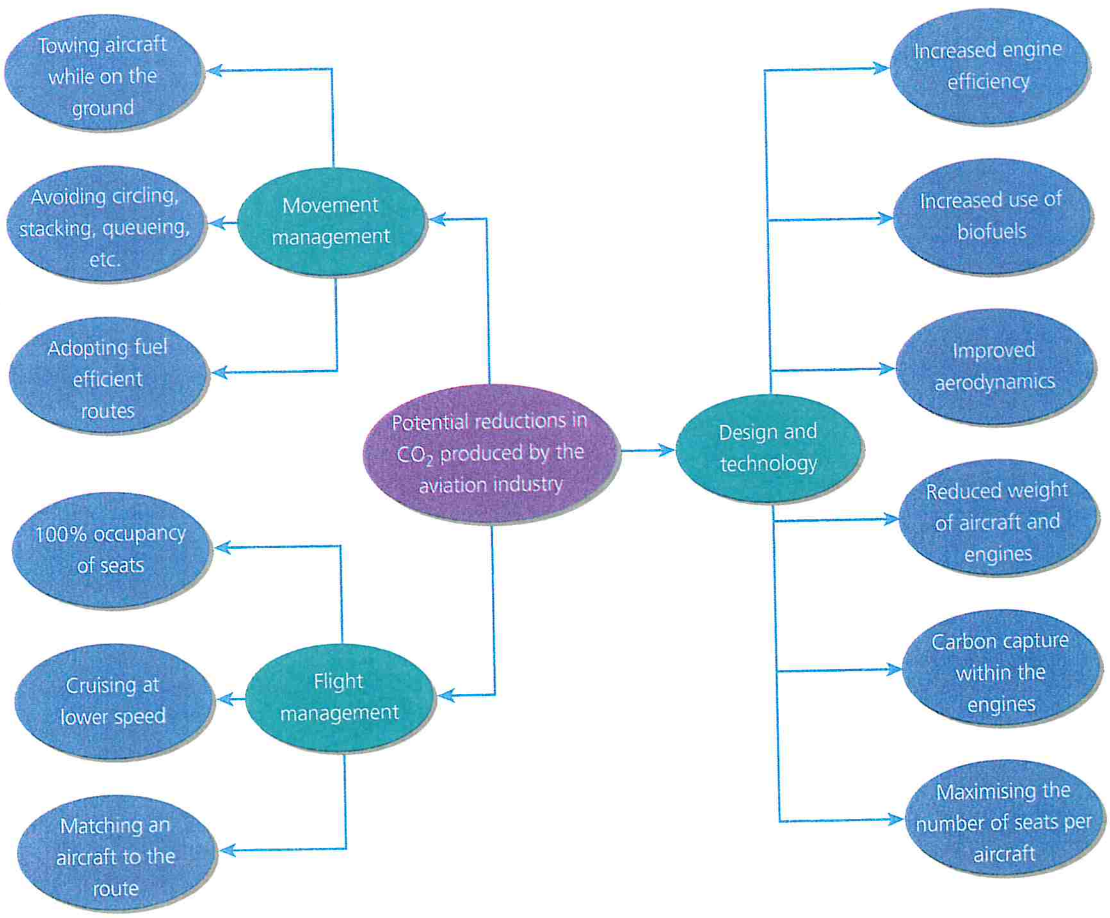

Figure 1.62 CO_2 mitigation within the aviation industry