5.5 CARBON CAPTURE AND STORAGE

Carbon capture and storage (CCS) is a way of reducing carbon emissions, which could be key to helping to tackle global warming. It's a three-step process, involving: capturing the carbon dioxide produced by power generation or industrial activity, such as steel or cement making; transporting it; and then storing it deep underground. Here we look at the potential benefits of CCS and how it works.

Carbon Capture and Storage (CCS) is a technology aimed at reducing greenhouse gas emissions, particularly carbon dioxide (CO_2), from large industrial sources such as power plants, cement factories, and steel mills. It involves capturing CO_2 emissions from point sources, transporting it to a suitable storage site, and securely storing it underground to prevent it from entering the atmosphere. Here's how CCS generally works:

1. **Capture:**

   CO_2 is captured from industrial processes or exhaust gases before they are released into the atmosphere. There are three main capture methods:

   - Post-Combustion Capture: CO_2 is captured from the flue gas produced during combustion in power plants or industrial facilities using chemical solvents or other absorption techniques.
   - Pre-Combustion Capture: Carbon is removed from fuel before combustion, typically through gasification processes, producing a gas stream primarily composed of hydrogen and CO_2. The CO_2 is then separated from the hydrogen before combustion.
   - Oxyfuel Combustion: Fuel is burned in an atmosphere of pure oxygen instead of air, resulting in a flue gas primarily composed of CO_2 and water vapor. The CO_2 is then separated from the water vapor using condensation or other methods.

2. **Transport:**

   Captured CO_2 is compressed into a dense fluid for transportation via pipelines, ships, or trucks to suitable storage sites.

3. **Storage:**

CO2 is injected deep underground into geological formations such as depleted oil and gas reservoirs, saline aquifers, or deep coal seams. These formations are typically thousands of feet below the Earth's surface, where the CO2 is stored securely and permanently, trapped by impermeable layers of rock.

CCS has the potential to significantly reduce CO2 emissions from industrial sources and help mitigate climate change. It can also enable the continued use of fossil fuels while transitioning to renewable energy sources, providing a bridge to a low-carbon future. Additionally, CCS can be combined with bioenergy production, known as Bioenergy with Carbon Capture and Storage (BECCS), which removes CO2 from the atmosphere while generating renewable energy.

However, CCS also faces challenges and considerations, including cost, technical feasibility, regulatory and permitting requirements, public acceptance, and the long-term integrity of storage sites. Despite these challenges, CCS continues to be explored and implemented in various regions around the world as part of comprehensive strategies to address climate change and reduce greenhouse gas emissions.

There are three steps to the CCS process:

1. Capturing the carbon dioxide for storage

The CO_2 is separated from other gases produced in industrial processes, such as those at coal and natural-gas-fired power generation plants or steel or cement factories.

2. Transport

The CO_2 is then compressed and transported via pipelines, road transport or ships to a site for storage.

3. Storage

Finally, the CO_2 is injected into rock formations deep underground for permanent storage.

CCUS can play a strategic role in global decarbonisation efforts in a number of ways. These include: (i) reducing emissions in ‘hard-to-abate’ industries (those that are particularly difficult to decarbonise); (ii) producing low-carbon electricity and hydrogen, which can be used to decarbonise various activities; and (iii) removing existing CO_2 from the atmosphere.

The various roles of CCUS can also help make the energy supply more diverse and flexible, in turn contributing to energy security, which has become a growing priority for governments around the world.

CCUS offers the most cost-effective option in many regions for the deep decarbonisation of a number of hard-to-abate industries, including iron, steel and chemicals. Moreover, CCUS is virtually the only known technological option for achieving deep emissions cuts in cement production, an industry that produces almost 7% of the world's emissions.

As a way of producing electricity and hydrogen in a low-carbon manner, CCUS can also feed into efforts to switch a wider range of sectors away from fossil fuels. CCUS can be installed on power plants running on coal, gas, biomass or waste. The low-carbon electricity created can then replace fossil fuels as an energy source, including in personal transport, space heating and the extraction of low- and medium-temperature heat in industry. Meanwhile, hydrogen can serve as a more direct substitute for fossil fuels in combustion processes, as feedstock in industrial applications, or in long-haul transport.

Growing evidence indicates that removing carbon dioxide from the atmosphere will be instrumental to reaching net zero emissions globally. The latest IPCC assessment report warns that the deployment of carbon dioxide removal (CDR) technologies is 'unavoidable' if net zero emissions are to be achieved. However, CDR should be used to complement, not replace, wider action on carbon mitigation. Two of the main ways of removing CO_2 from the atmosphere – bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS) – both share a technological foundation with CCUS. DACCS enables the capture of CO_2 directly from the atmosphere while BECCS can result in CO_2 removal on a net basis where the biomass is sustainably sourced.

High cost is perhaps the most commonly cited drawback of CCUS. CCUS facilities are capital-intensive to deploy and energy-intensive to operate, making them particularly expensive when energy costs are high. There are also risks and uncertainties around the technological performance of CCUS operations. However, given tightening climate targets and increasing carbon prices, reducing emissions is not optional. Therefore, the cost and risks of CCUS should be compared with alternative decarbonisation pathways rather than with 'doing nothing'. Limiting the availability of CCUS is actually likely to increase reliance on technologies that are currently more expensive and at earlier stages of development. For example, incorporating CO_2 capture into steel production raises estimated costs by less than 10%, but approaches based on hydrogen produced from renewables can raise costs by 35–70% compared with conventional production methods.

The cost of CCUS will continue to fall as the market expands and technologies develop. For example, the cost of CO_2 capture in power generation reduced by 35% from the first to the second large-scale CCUS facility in that sector. Costs also need to be assessed in terms of wider economic benefits. Notably, CCUS can allow the continued operation of energy-intensive industries in a net zero-compliant way, in turn preventing the many jobs and assets that they support from becoming stranded.

CO_2 leakages from storage sites could lead to possible environmental damages and the reversal of intended emissions savings. However, strong regulations for projects' selection, management and monitoring of storage sites are in place and being developed. Furthermore, many of the potential storage sites being considered are well-understood geological formations that have already stored gas and CO_2 naturally for millions of years, implying that leakage risk overall is relatively small

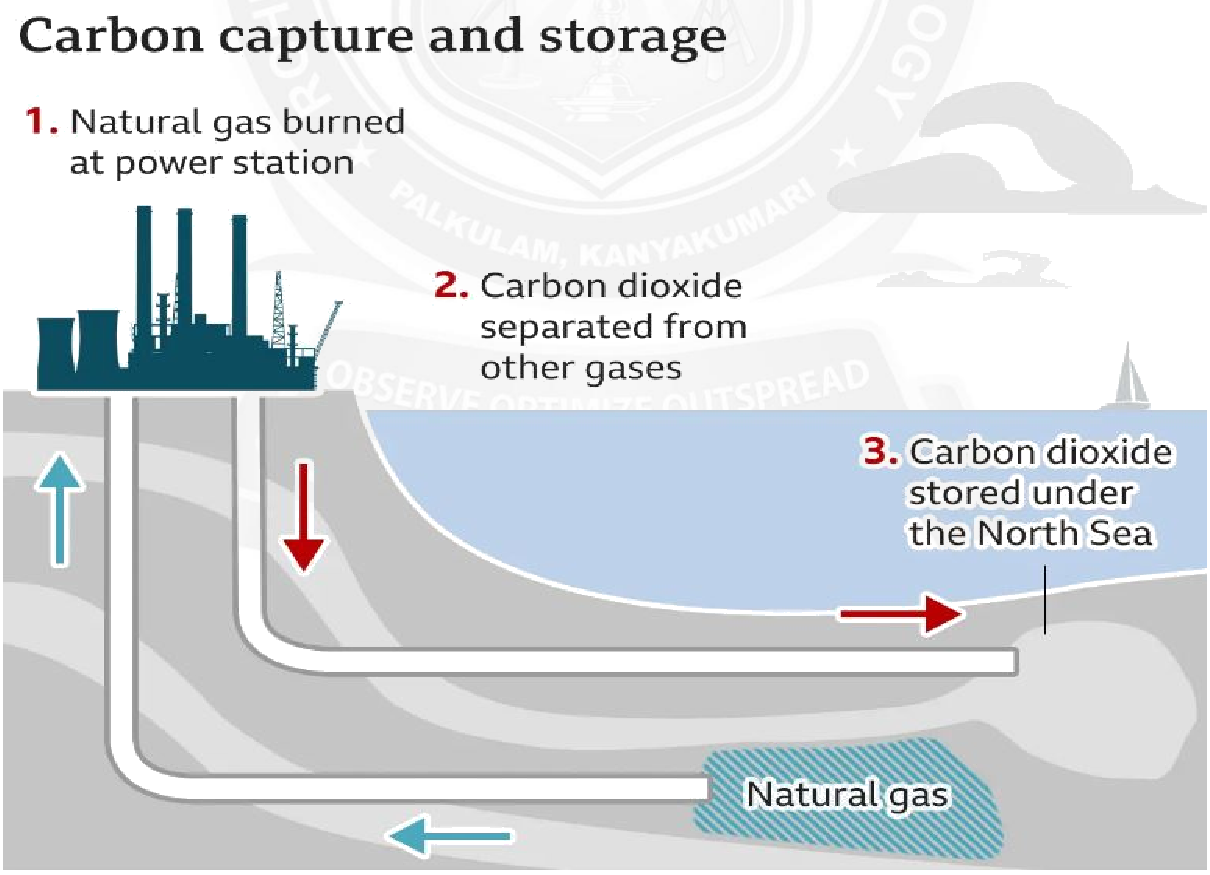

FIG.5.1.1 CARBON CAPTURE AND STORAGE

What are the costs and risks of CCS?

CO_2 storage regulations require that storage operations be rigorously monitored for a number of reasons, including:

- verifying the amount and composition of CO_2 being put into underground storage
- understanding how the CO_2 is behaving once underground
- providing early warning if things are not going as planned
- providing assurance of long-term storage integrity
- measuring any leakage that might occur

Regulatory frameworks governing geological CO_2 storage are being developed worldwide. In Europe, an EC Directive says that the issues of leakage and potential long-term stewardship of storage sites must be addressed if the potential for CO_2 capture and storage to provide substantial reductions in atmospheric CO_2 emissions is to be realised.