Technology unveiled

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Drilling site

Carbon capture

In the fight against climate change, 'CCS' (Carbon Capture (CO_2) and geological Storage) technology has been identified as a necessary solution for reducing CO_2 emissions caused by human activity. These emissions currently represent 30 billion tonnes per year, but only half of this amount is captured naturally in the oceans, soils and forests. Across the globe, 22% of CO_2 emissions derive from transport and 66% from industrial facilities (fossil-fired power plants, iron and steel works, cement plants, refineries, etc.). All scenarios, such as those considered by the International Energy Agency (IEA) and the European Union, rely on CCS technology to reduce carbon emissions. France, for example, has made a commitment to lower its carbon emissions to 25% of the level reached in 1990, with a deadline set for 2050. CCS is practically the only solution for reducing emissions from industrial installations.

CO_2 storage

AN INNOVATIVE PROCESS FOR INJECTING CO_2 INTO DEEP GEOLOGICAL FORMATIONS

Carbon capture aims to trap carbon dioxide and stop it from being released into the atmosphere through an industrial process that makes use of innovative technology. The carbon dioxide is then compressed and transported through a pipeline or by ship to deep geological formations with suitable characteristics, particularly in terms of containment, into which it is injected. The EDF Group stands out among electricity producers thanks to a carbon intensity of less than 100 gCO_2/kWhe (compared to an average of 346 gCO_2/kWhe in Europe) due to its nuclear power plants in France and the UK. Nevertheless, the Group continues to proactively reduce its emissions through a CCS programme that has been in place since 2007 and brings together production, thermal engineering, research and development, and subsidiaries. Its aim is to ensure that the Group has a comprehensive view of technological changes and costs so that it can prepare itself as well as possible with regards to choices which will have to be taken in the future.

A tried and tested transport system

More than 50 million tonnes of CO_2 are transported through around 6,000 kilometres of pipes every year in the United States. In fact, the first pipeline was commissioned in 1972. Most of this CO_2 is of natural origin and is used by the oil industry for enhanced oil recovery. The scientific community does not, therefore, anticipate any sticking points as far as the 'transport' link of the CCS chain is concerned.

STORING CARBON DIOXIDE

Trapping CO_2 to fight global warming

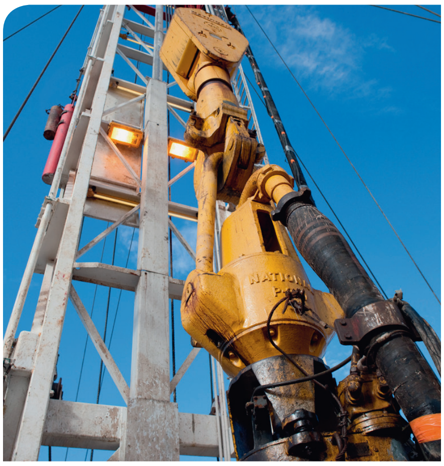
Carbon dioxide needs to be injected at a depth of more than 800 metres to remain in its dense phase and, therefore, enable the maximum mass to be stored within a given volume. It can be stored in particular geological formations with the appropriate characteristics:

- Deep saline aquifers: porous geological formations called 'reservoir rock' containing brine unsuitable for consumption.
- Depleted hydrocarbon (oil or natural gas) reservoirs.
- Deep coal seams that cannot be exploited.
- Certain rocks with a specific chemistry, such as basalts.

Reservoirs in abundance

Our planet has numerous reservoirs suitable for the geological storage of carbon dioxide. In fact, the potential capacity worldwide could be as much as 10,000 billion tonnes. Deep saline aquifers offer the greatest storage capacity and are fairly well distributed geographically. However, their precise capacity and characteristics remain to be evaluated (unlike the hydrocarbon reservoirs currently in use). This time-consuming and costly work should start with an analysis of the most promising targets to ensure that the deployment of the technology is not hampered by a lack of storage site availability. In France, large sedimentary basins (the Paris Basin and the Aquitaine Basin) and a small number of hydrocarbon reservoirs at the ends of their operational lives, exist. By focusing considerable efforts on exploration, some of these areas could be found suitable for the geological storage of CO_2. Total has been injecting CO_2 into a depleted natural gas reservoir in Lacq (Pyrénées Atlantiques), at a depth of 4,500 metres, since January 2010.

The EDF Group is currently developing expertise on the 'storage' link of the chain and is participating in projects with specialists in the field.



Drilling machine

When carbon dioxide is stored in a deep saline aquifer, the injected CO_2, which is lighter than the brine in the reservoir, migrates upwards as far as the impermeable cap rock, which blocks its movement (forming a structural and/or stratigraphic trap). Some of the CO_2 remains trapped in the pores of the reservoir rock (residual trapping), while some dissolves in the salt water. When this salt water is weighed down, it tends to migrate towards the bottom of the reservoir and forms dissolution fronts in the brine (trapping through solubilisation). After thousands of years, the dissolved CO_2 will form other minerals (mineral trapping) by reacting with the reservoir rock. The relative importance of these different mechanisms varies according to the geology of the site. Managing the injection pressure (in fact, the overpressure in relation to the reservoir's initial pressure) is key to guaranteeing the integrity of the storage system (reservoir and cap) and the long-term containment of the CO_2.

KEY FACTS

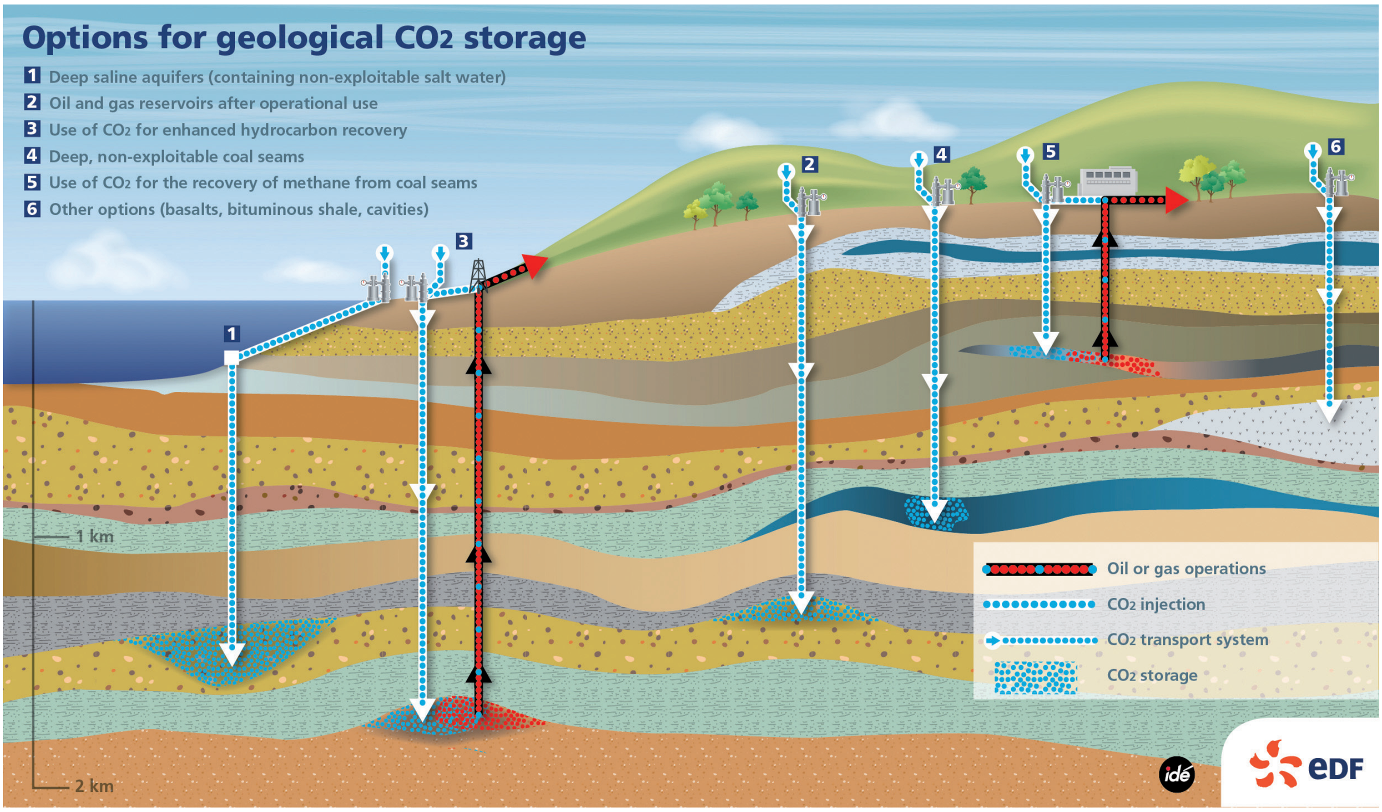
Proven examples of CO_2 storage

Sleipner
- North Sea, Norway
- Statoil, 1996
- Saline aquifer
- 1 Mt per year injected
- Capture on processing of natural gas
- Storage at depth of 1,000 m

In-Salah
- Sahara, Algeria
- BP, Sonatrach and Statoil, 2004
- Saline aquifer
- 1 Mt per year injected
- Capture on processing of natural gas
- Storage at depth of 1,900 m

Snøhvit
- Barents Sea, Norway
- Statoil, 2008
- Saline aquifer
- 0.7 Mt per year injected
- Capture on processing of natural gas since 2008
- Storage at depth of 2,400 m

Weyburn
- Saskatchewan, Canada
- Cenovus, 2000
- EOR-CO_2
- 3 Mt per year injected
- Capture on coal gasification synthetic gas (North Dakota)
- Storage at depth of 1,400 m



DID YOU KNOW?

Natural CO_2 deposits have existed in certain sedimentary basins for millions of years (such as at Montmiral in France and at various sites in the USA). Some of these deposits contain more than a billion tonnes of CO_2.

These veritable natural laboratories provide us with ideal data on both time and spatial scales, to help us supplement, check and validate our predictive geomechanical and geochemical models, as well as understand the physico-chemical processes that occur over the long term.

Managing the risks of CCS

Carbon capture and geological storage technology meets safety requirements throughout the entire process, both at the surface and underground, and over the short and the long term. A whole raft of observational and measuring tools are used for monitoring the sites to track the development of the storage process, for making comparisons with 'expected' behaviour (calculated through prior simulations) and for checking that there are no leaks. All four of the world's industrial-scale storage sites make use of these tools. This is what sets Weyburn apart as a CO_2 storage operation, as other hydrocarbon production sites that also use CO_2 for EOR do not have their own specific monitoring tools. Tried and tested systems are used for managing the safety of carbon capture and transport, in accordance with the legal framework for industrial installations. However, the geological storage of CO_2, as a newer process, has been governed since 2009 by a European directive, transposed into French law, which imposes a requirement for permanent and environmentally-safe storage methods, which prevent and control the rise of CO_2 towards the surface, while causing minimal disturbance to the underground environment. To achieve this, before any CO_2 is injected, the envisaged storage site is studied in detail to ensure that it can offer all guarantees of safety: geological stability (no active faults), a leaktight cap rock and no risk of contaminating the underground water. When the site is in operation, and during the closure phase, rigorous preventive measures are implemented, and monitoring continues for several decades after the site has closed, using the tools described previously. Any CO_2 moving upwards is detected in the intermediate layers before it reaches the surface and appropriate

Hazards associated with CO_2

CO_2 is neither explosive nor flammable. It is harmless in low concentrations but is dangerous to living organisms and humans (leading to a loss of consciousness or asphyxia) when the concentration exceeds 5% (confined environment or basin relief).

Outlook

Road maps are generally counting on the commercial availability of CCS technology from 2020. However, due to delays in the industrial demonstration stage, the first scale 1 installations are expected to emerge in around 2025. Transport and storage are less expensive than capture and, in principle, the technical risks are under control. Currently, storage is being considered in hydrocarbon fields after operational use, or in saline aquifers. However, the likelihood of hazards appears to be greater for storage in saline aquifers, which have not yet been sufficiently characterised. The main challenge associated with the bulk transport of CO_2 relates to the infrastructure (pipeline system) that will need to be installed across areas equating to large countries (China, United States, etc.). One problem is the willingness of local populations to accept the geological storage of CO_2, particularly on land, and several countries have turned their backs on genuine prospects of on-shore storage in favour of more complex and costly off-shore solutions. CCS development and deployment are also coming up against limitations. As far as storage is concerned, the following examples can be cited:

- Funding mechanisms that are insufficient for demonstrators but stable over time for industrial application.
- A European directive that is transcribed differently in the individual Member States.
- A high level of uncertainty over the available storage capacity.
- A financial risk for initial projects, especially in saline aquifers.
- Delays with regard to storage characterisation, transport system construction and administrative authorisations.
- Transport system and storage site constraints on the supply of CO_2 (whether the system is simple or more complex, combining clusters of plants connected to multiple storage sites).
- The availability of a skilled workforce to deploy the transport architecture and put the storage sites into service.
- Public perception and the acceptability of on-shore storage. The public still knows very little about CCS technology and barely one in ten Europeans has heard of the concept.

Nicolas Vaissière and Fabrice Chopin, EDF R&D

List of terms

Saline aquifer: porous and permeable geological formation containing salt water unsuitable for human consumption.

CCS: Carbon (CO_2) Capture and geological Storage.

Dense phase: the CO_2 is compressed beyond the critical point, presenting interstage characteristics between a liquid and a gaseous state, with a high density and a low viscosity: ideal conditions for transport and storage (little pressure loss during transport and injection, and optimal use of the available storage volume).

EOR/EGR: Enhanced Oil Recovery / Enhanced Gas Recovery.

Cap rock: impermeable, non-porous rock (argillite, evaporite) that confines the fluids contained in the reservoir rock.

Reservoir rock: porous, permeable rock containing, or able to contain, an injected fluid due to its appropriate petrophysical properties.

Brine: aqueous salt solution, saturated or highly concentrated.

> for further information

Club CO_2: http://www.captage-stockage-valorisation-co2.fr/

In Salah Gas: http://www.insalahco2.com/

Statoil: http://www.statoil.com/en/technologyinnovation/newenergy/co2management/pages/sleipnervest.aspx

CO_2 Geonet (European research laboratory): http://www.co2geonet.com

ZEP (Zero Emission Platform): http://www.zeroemissionsplatform.eu/

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