International Energy Agency
Secure Sustainable Together

Carbon Capture and Storage:

The solution for deep emissions reductions

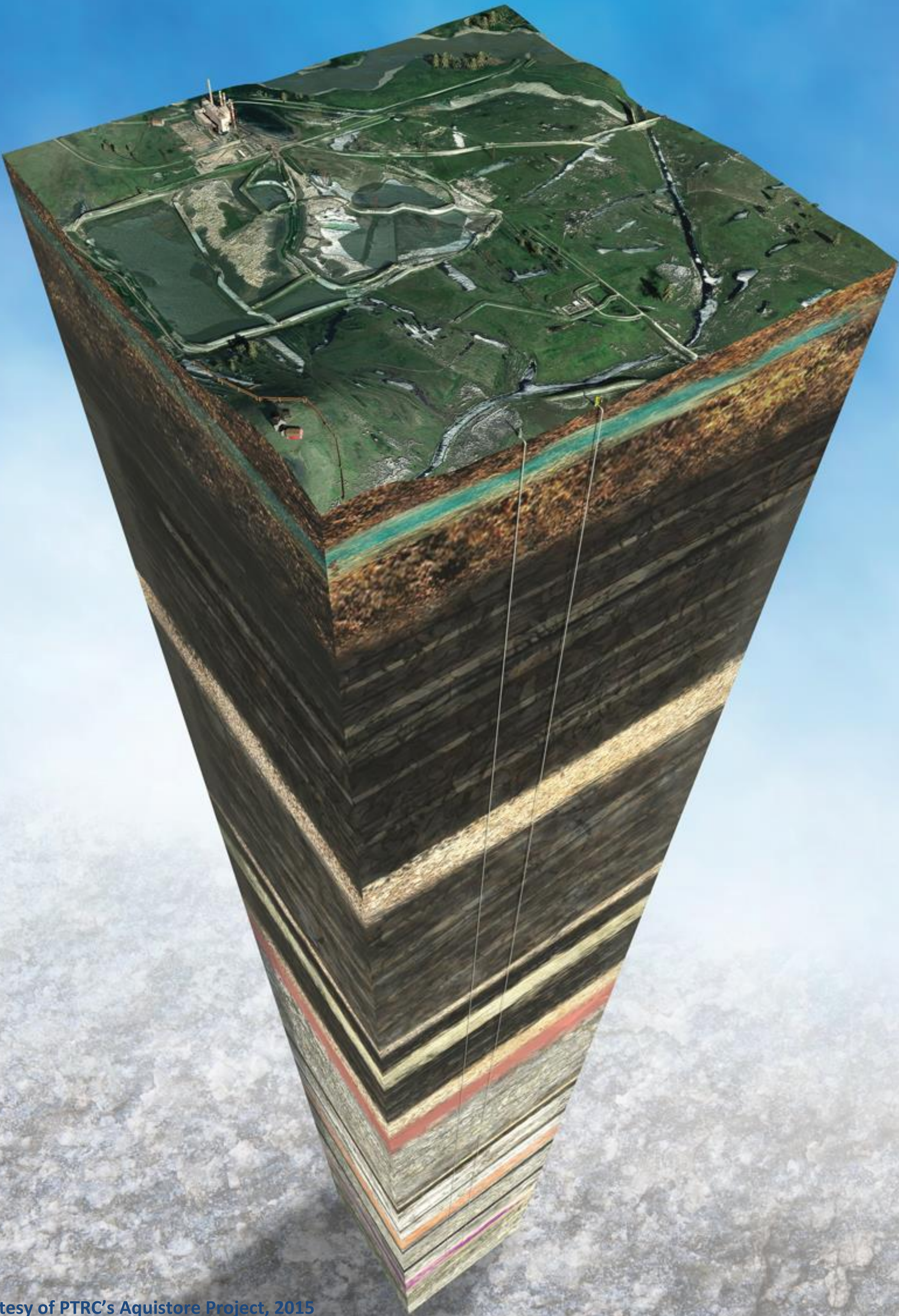

Image courtesy of PTRC's Aquistore Project, 2015

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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The European Commission also participates in the work of the IEA.

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1 Our two-degree future requires carbon capture and storage

Carbon capture and storage (CCS) is the only technology able to deliver significant emissions reductions from the use of fossil fuels. CCS can reduce emissions not only from power generation, but also from industrial sectors such as iron and steel, refining, petrochemical, and cement manufacturing.

According to International Energy Agency (IEA) modelling, CCS could deliver 13% of the cumulative emissions reductions needed by 2050 to limit the global increase in temperature to 2°C (IEA 2DS). This represents the capture and storage of around 6 billion tonnes (Bt) of CO_2 emissions per year in 2050, nearly triple India's energy sector emissions today.

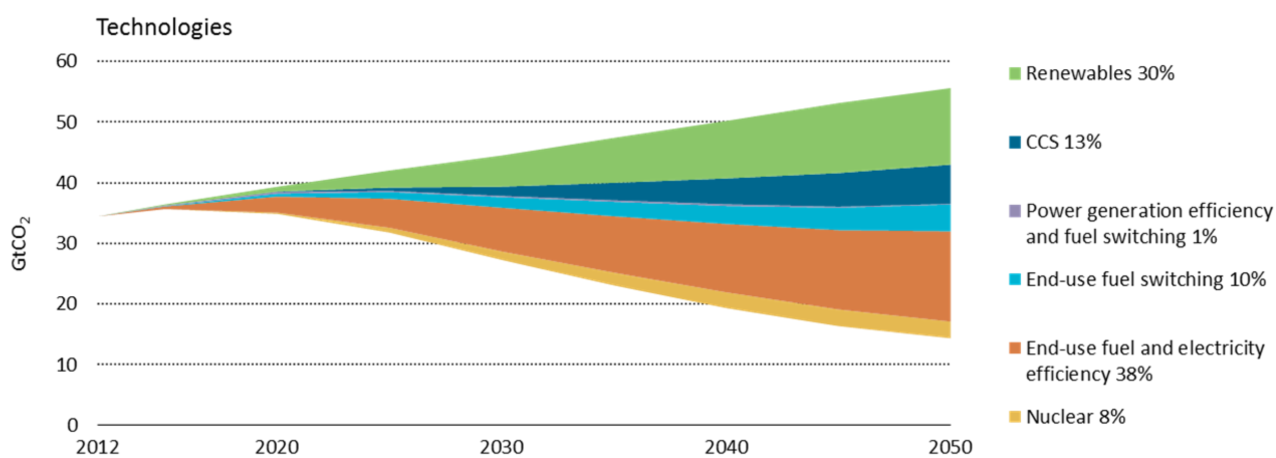
Half of this captured CO_2 in the 2DS would come from industrial sectors, where there are currently limited or no alternatives for achieving deep emission reductions. While there are alternatives to CCS in power generation, delaying or abandoning CCS in the sector would increase the investment required by 40% or more in the 2DS, and may place untenable and unrealistic demands on other low emission technology options.

Without CCS, long-term global climate goals may be unobtainable:

"Many models could not limit likely warming to below 2°C if bioenergy, CCS and their combination (BECCS) are limited"

International Panel on Climate Change, 5th Assessment report, 2014

Figure 1: Contribution of technologies and sectors to global cumulative CO_2 reductions



Source: IEA Energy Technology Perspectives 2015

Not "business as usual" for fossil fuels

Fossil fuels dominate the global energy mix today, with coal, gas and oil accounting for 81% of global primary energy demand in 2013. Even as the world acts to limit temperature increases to 2°C, fossil fuels will remain a major feature of the global energy mix and will account for around 40% of primary energy use in 2050. A 2°C pathway represents a significant departure from "business-as usual" for fossil fuels. Coal use in power generation falls to around one-third of current levels, with 95% of coal-fired generators equipped with CCS. Forty percent of gas-fired power generation will also need to be equipped with CCS in 2050.

This has implications for decisions to invest in fossil fuel-based power generation and industrial facilities today, as most of these large capital investments are based on assumed lifetimes of several decades – 30 to 40 years for a power plant. Retrofitting of CCS would prolong the economic life of these assets and provide a form of insurance against asset stranding. China alone has an installed capacity of around 860 gigawatts (GW) of coal-fired power, and IEA analysis suggests that more than one-third of this fleet could be candidates for CCS retrofit.

2 CCS is up and running...

Today, there are 15 large-scale facilities around the world capturing 27 million tonnes (Mt) of CO_2 every year. The Sleipner oil and gas project in Norway has had almost 20 years of successful CCS operations, storing around 1 Mt of CO_2 per year from a natural gas processing facility. In the United States, CO_2 has been used for enhanced oil recovery (EOR) for several decades, facilitated by an existing network of CO_2 transport pipelines which span more than 6,600 km.

15 large-scale CCS projects are already operating globally, with a further 7 expected to come online by 2018

The global portfolio of CCS projects now includes the Boundary Dam Project in Saskatchewan, Canada, which in October 2014 became the first operating coal-fired power plant to apply CCS. Two additional projects in the power sector, the Kemper County project in Mississippi and the Petra Nova Carbon Capture Project in Texas, are due to come into operation in 2016. The Shell Quest CCS project, launched in November 2015, is the world's first CCS project to reduce emissions from oil sands upgrading.

All of these projects are providing valuable experience in operating large-scale CO_2 capture facilities, managing large CO_2 injection, and monitoring the behaviour of CO_2 underground. The "learning by doing" benefits of this are considerable: for example, after only 12 months of operation, the Boundary Dam project owners believe they can reduce the cost of the next plant by 30%.

In addition to the operating projects, there are a total of seven large-scale CCS projects under construction and expected to commence operation before 2018. These include the Gorgon Carbon Dioxide Injection Project in Australia, which will be the world's largest storage project with around 3.4 Mt of CO_2 stored every year. A further 11 projects are in advanced stages of planning.

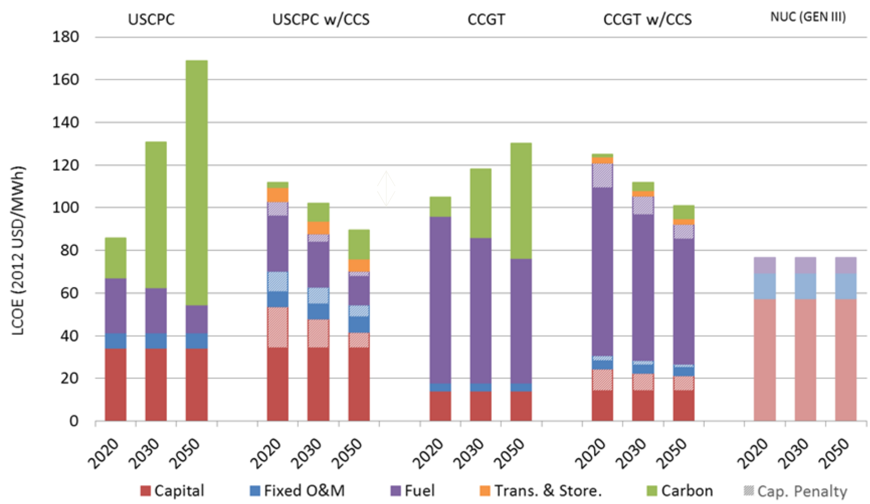
Boosting the number of large-scale projects under development is a priority. These projects are critically important in providing commercial experience, enabling key technologies to be refined and cost reductions to be achieved. Greater diversity in the project portfolio, particularly for CCS applied to electricity and industrial facilities, is also needed to pave the way for widespread deployment.

Boundary Dam Project, Canada
Image courtesy of Saskpower

3 ...and may be less expensive than you think

CCS applied to power generation could be cost-competitive with other dispatchable electricity generating technologies within the next decade. In the IEA 2DS scenario, technical improvements, relative differences in fuel prices and increasing carbon constraints mean that CCS-equipped power competes with other dispatchable low-carbon options, such as concentrated solar power with energy storage, by 2025. In certain markets in Asia, high gas prices and low coal prices could make coal-fired power with CCS competitive with gas-fired power at a carbon price as low as USD 35 per tonne by 2030 (Figure 2).

Figure 2: Cost of electricity of CCS-equipped power plants in Japan in IEA 2DS scenario



Source: IEA Energy Technology Perspectives 2015

Beyond the power sector, there are early opportunities for CCS deployment where policy settings and strategic factors align. For example, many of today's large-scale CCS projects are in natural gas processing, hydrogen production, bioethanol and fertiliser manufacture where the separation of CO_2 is already an inherent part of the process. In gas processing, CCS abatement costs can be as low as USD 5-20 per tonne of CO_2. In other industrial applications, CCS costs are currently higher; for example the cost of a tonne of CO_2 avoided in steel or cement production could start from USD 60 per tonne. The continued economic importance of commodities such as steel, cement and fertiliser underscores the importance of enhanced R&D efforts to reduce CCS costs for industrial applications.

The Sleipner oil and gas project in Norway has been injecting and storing CO_2 for 20 years

Sleipner Platform, North Sea
Image courtesy of Statoil

4 CCS: Not just a coal technology

Although often perceived as a coal technology, CCS is actually a suite of technologies that can be adapted and applied to a range of situations. Many of the early opportunities for large-scale CCS have in fact been associated with natural gas production, and in some jurisdictions with low gas prices, such as the United States, the potential opportunities for CCS applied to gas-fired power generation may be greater than that for coal.

Notwithstanding the potential range of applications of CCS, the scale and nature of CCS technology's deployment is expected to vary greatly between countries and regions. In some countries, CCS may offer a niche solution to address specific CO_2 emissions sources, while in other countries, particularly China and the United States, it could grow to become a major industry in itself. In fact, almost 80% of CCS in the IEA analysis is expected to be deployed in China and the United States.

Applications of CCS technologies

Industrial sectors – steel, cement, chemicals, fertiliser, hydrogen, refining

In many industrial sectors, deep emissions reductions are typically not possible without CCS. The global portfolio of operating CCS projects includes hydrogen and fertiliser production, and in November 2015 the Shell Quest CCS project became the first CCS project to reduce emissions from oil sands processing. Construction is underway on the world's first large-scale CCS project in the iron and steel sector, the Abu Dhabi CCS project in the United Arab Emirates.

Natural gas processing

Excess CO_2 content in natural gas streams is a candidate for early CCS deployment, as the CO_2 must be separated from the gas before it can be sold. This CO_2 can then be stored rather than being vented into the atmosphere. Both Norway and Australia have implemented projects on natural gas production, with the Australian Gorgon Project set to become the world's largest CO_2 storage project in 2016, storing more than 3 $MtCO_2$ per year.

Gas-fired power

CCS applied to gas-fired power generation can play an important role in a global climate change response. By 2050, the global average CO_2 intensity of all power generation in a 2DS falls to 40 grams per kilowatt hour, almost nine times lower than the natural gas power fleet. In regions with low gas prices, such as the United States, advancing CCS on gas-fired power might be more favourable than for coal.

Coal-fired power

Fuel cost issues in the power sector are key drivers and CCS on coal-fired power may turn out to be particularly attractive in the Asian market, including substantial retrofitting opportunities in China. The world's first commercial-scale CCS plant applied to coal-fired power generation, SaskPower's Boundary Dam, commenced operation in 2014.

CCS with bioenergy (BECCS)

Offers permanent net removal of CO_2 from the atmosphere, or "negative emissions" by using biomass that has removed atmospheric carbon while growing, and then storing the emissions from combustion underground. The first CCS projects on biofuel production are already a reality.

Enhanced oil recovery using CO_2 (CO_2-EOR)

EOR has been a major driver of many early CCS projects, providing a revenue stream for the captured CO_2. In North America and in the Middle East in particular, there is potential to expand the use of EOR for climate change purposes by combining it with permanent CO_2 storage. This requires that EOR projects implement measures to verify that the CO_2 remains underground.

5 CO_2 storage assets: A strategic investment

There is an abundance of geological formations suitable for CO_2 storage globally; however, efforts to characterise and convert these potential storage resources to commercial capacity must be accelerated if CCS is to be available for widespread deployment from the 2020s.

CCS investments will require a high level of certainty that sufficient storage capacity is available and can be accessed at reasonable cost before making a final investment decision. For greenfield storage sites, this process can take close to a decade. While appropriate site selection and characterisation are critical, a key part of this process will also be effective community engagement, recognising that there may be a low level of awareness and acceptance of CO_2 storage amongst local communities (see box below).

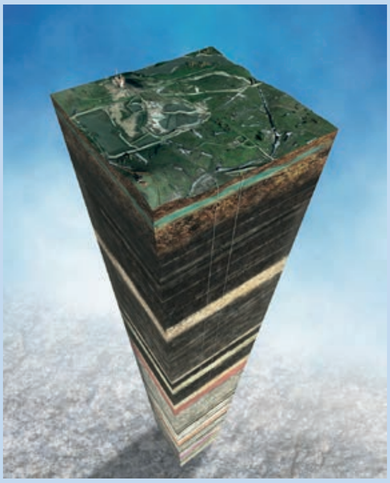
Governments can take a major step towards accelerating CCS deployment by prioritizing the identification of CO_2 storage sites as a strategic national asset. This involves undertaking pre-commercial exploration and assessment to develop a publicly available, base-level understanding of national or regional CO_2 storage resources as a precursor to detailed characterisation by CCS project proponents. Governments should also consider opportunities to lower the costs of CO_2 transport and storage through joint development of infrastructure, and investigation of options for future ownership and operation.

Engaging communities on CO_2 storage

Successful deployment of CCS will require improved efforts to ensure local communities and the general public understand and accept the technology. Permanent geological storage of CO_2 is a relatively new and unknown concept for many people and will raise legitimate concerns about safety and risks. Are such projects safe for people and ecosystems? Will the CO_2 remain safely underground? Scientific and practical experience demonstrates that well-chosen and appropriately managed storage sites can permanently and safely retain CO_2, and it is important that this is effectively communicated.

Project proponents must also consult with local communities at the earliest possible opportunity, ensuring that those near the storage site are well-informed about the localised impacts, risks and benefits of the project. There are many examples where these communications have been managed successfully, for example in North America where local populations have accepted projects that inject CO_2 for either EOR or permanent storage. In other cases, such as in Germany and the Netherlands, local populations have effectively stopped CO_2 injection activities.

Governments, NGOs and the scientific community will also have an important role to play in communicating the role of CCS as part of an effective global or national response to climate change. This includes ensuring that CCS is included in national energy policy frameworks, alongside other "mainstream" low-carbon technologies.



Top image: courtesy of CO2CRC Ltd
Bottom image: courtesy of PRTC's Aquistore Project, 2015

6 Combining enhanced oil recovery with CO_2 storage for profit

CO_2-EOR is a process where CO_2 is injected in declining oil fields to boost oil production. The majority of the injected gas remains in the reservoir and the portion that re-emerges with the produced oil is separated from the oil and re-injected in a closed loop. The potential of CO_2-EOR varies considerably by region. There is substantial technical potential for CO_2-EOR in North America and the Middle East, and also in Russia, North Africa and Central Asia.

Combining enhanced oil recovery (EOR) with permanent CO_2 storage, or "*EOR+*", represents a significant win-win opportunity. According to IEA analysis, *EOR+* could theoretically store around 240 Gt of CO_2 – more than twice the storage required in the IEA 2DS – while increasing global oil production by as much as 375 billion barrels by 2050.

Ultimately, the CO_2 must be stored underground permanently if CO_2-EOR is to play a role in combatting climate change. Today's CO_2-EOR operations are carried out with the primary objective of maximising oil output with limited or no focus on CO_2 storage. Moving to an *EOR+* model, with a dual objective of permanent CO_2 storage, will require a shift from current practice and involve taking on additional activities associated with monitoring and verification of the stored CO_2. At a minimum, these activities include:

i) additional site characterisation and risk assessment to evaluate the storage capability of a site;
ii) additional monitoring of vented and fugitive emissions;
iii) additional subsurface monitoring; and
iv) changes to field abandonment practices.

A carbon price or appropriate regulatory mechanism would be needed to facilitate this shift from traditional EOR practices to *EOR+*. However, *EOR+* can be a very profitable activity since under increasing carbon prices in the future the *EOR+* operator will be able to combine revenue from additional oil production and simultaneous CO_2 storage.

The emissions reduction benefit of *EOR+* is tempered by the production of additional fossil fuels from which the majority of the carbon is inevitably emitted back to the atmosphere. However, IEA analysis indicates that using CO_2 in *EOR+* projects can generate net emissions reductions, particularly when more CO_2 is used per barrel of oil produced than has traditionally been the case.

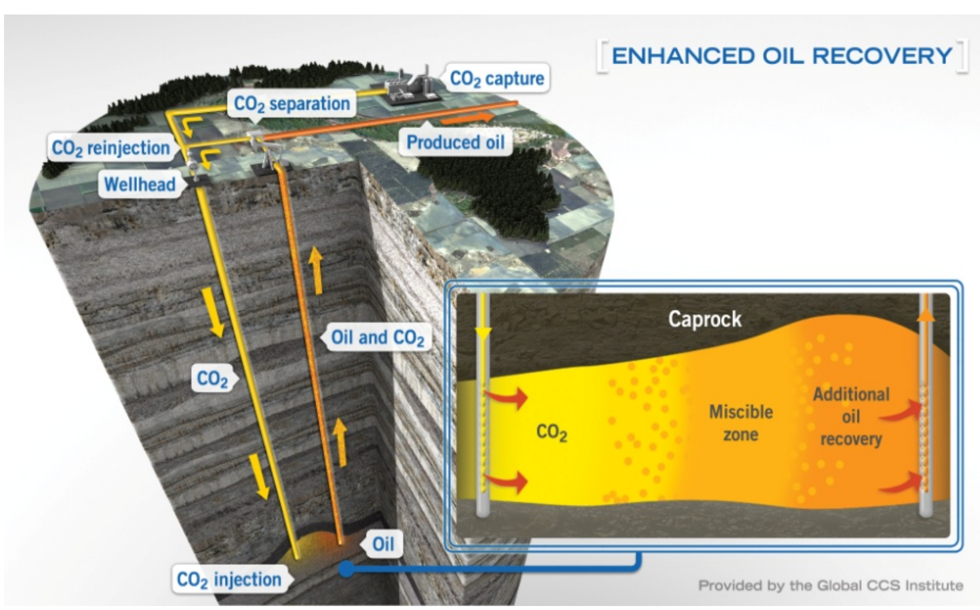


Image courtesy of the Global CCS Institute

CCS is an essential part of the climate solution

1. A 2-degree pathway requires deployment of CCS in both industrial and power applications.
2. CCS is already a reality. There are currently 15 large-scale CCS projects operating throughout the world, with 7 more expected to come online by 2018.
3. CCS could be competitive with other dispatchable, low-emission generation technologies by 2030.
4. CCS is not just a coal technology. It is needed to reduce emissions from a range of applications, including steel and cement manufacturing.
5. Timely development of CO_2 storage resources will be critical for widespread CCS deployment.
6. EOR with CO_2 storage offers a major win-win opportunity, generating net emissions reductions alongside oil production.

CCS requires targeted policies – and industry commitment

Efforts by governments and industry to support the development and deployment of CCS have not been commensurate with its potential contribution to global climate targets. The lack of policy attention carries the risk of CCS not being available at the scale required to deliver necessary emissions reductions in a timeframe consistent with climate objectives.

Targeted polices and increased investment will be needed to put CCS on the path to deployment, in the same way that targeted support has underpinned the development and deployment of renewable energy technologies. The IEA has identified priority actions for governments and industry:

- Introduce financial support mechanisms for demonstration and early deployment of CCS, including capital grants and operating support. Recognising that almost three-quarters of CCS deployment must occur in non-Organisation for Economic Co-operation and Development countries, consideration should be given to establishing an international facility to fund a project in an emerging economy.
- Implement policies that encourage CO_2 storage exploration, characterisation and development. The process to prepare a site for CO_2 storage will take several years and work must speed up immediately.
- Increase investment in globally co-ordinated research, development and demonstration activities to reduce the cost of capture technologies, including in industrial applications.
- Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology and the importance of its deployment.
- Encourage efficient development of CO_2 transport infrastructure by anticipating locations of future demand centres and future volumes of CO_2.

Gorgon Project, Australia
Image courtesy of Chevron

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