OIL AND GAS CLIMATE INITIATIVE

CCUS IN SAUDI ARABIA

The value and opportunities for deployment

A REPORT FROM THE
OIL AND GAS CLIMATE INITIATIVE

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The Oil and Gas Climate Initiative (OGCI) aims to accelerate the industry response to climate change and scale up practical solutions for a net zero future.

Scaling up carbon capture, utilization and storage (CCUS) is an essential tool to achieve both of these goals, and is therefore one of OGCI's top priorities. CCUS opens up opportunities to reduce emissions on a huge scale, make low-carbon products, accelerate the emergence of a hydrogen economy and provide the infrastructure to remove carbon dioxide permanently from the atmosphere. It is a key enabler for low carbon energy transitions.

In 2019, OGCI launched the CCUS KickStarter initiative which focuses on creating CCUS-enabled industrial hubs to leverage economies of scale and drive down costs through accelerated deployment. As part of this work, we are evaluating high-potential hubs around the world and exploring the value and potential of CCUS for specific countries. In 2020, we supported the inaugural iCCUS conference held in Saudi Arabia.

This paper is based on our analysis and engagement in Saudi Arabia, working closely with our member company Saudi Aramco. OGCI is working this year to extend the analysis to other GCC countries.

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Scaling up CCUS

CCUS technology is required globally to meet climate goals in a cost-effective manner. In the Intergovernmental Panel on Climate Change (IPCC) scenarios, an average of 13 gigatonnes of carbon dioxide needs to be captured annually by 2060 to keep global warming below 1.5°C below pre-industrial levels[1]. Almost all IPCC scenarios involve CCUS, and the International Energy Agency estimates that with limited carbon dioxide storage (and hence CCUS), the cost of decarbonization could be $4 trillion greater globally[2]. Currently, around 20 large-scale CCUS projects store around 45 million tonnes globally per year[3] - to meet climate mitigation targets more than 2,000 large-scale facilities will be needed by 2040.

A massive scale-up is clearly needed if CCUS is to develop as required to support the aims of the Paris Agreement. The good news is that CCUS is gaining significant momentum internationally as more and more countries set net zero targets by mid-century. As they explore pathways to realize their ambitions – and invest in post-Covid infrastructure and jobs – there is heightened interest in carbon dioxide storage and a growing realisation that CCUS is essential to fully decarbonize hard-to-abate sectors, like cement, steel and petrochemicals. Plans for over 30 commercial facilities have been announced in the past three years, and potential investment in CCUS projects nearing construction has more than doubled since 2017 to US$27 billion[4].

COUNTRIES TAKING CONCRETE POLICY MEASURES TO SCALE UP CCUS DEPLOYMENT:

- The **US** has a federal production tax credit, known as 45Q, that rewards companies on a per ton basis for anthropogenic carbon dioxide securely stored geologically in approved reservoirs and aquifers. The deadline for start of construction was recently extended to the end of 2025 and allows six years for projects to come online.
- **China** has around 30 facilities advancing through various stages of development, including CNPC's China-Northwest hub; CCUS is seen as key to reaching the target of carbon neutrality by 2060.
- **Norway's** parliament agreed in January 2021 to invest in the Longship/Northern Lights large-scale full chain CCUS project and construction has begun.
- The **Netherlands** created financial mechanisms to support large-scale CCUS hub projects, including the Rotterdam/Porthos hub, as part of its strategy to reduce industrial emissions by 2030.
- The **UK** is supporting several CCUS clusters through its industrial decarbonization strategy, including Net Zero Teesside.
- Policy enablers for CCUS projects in **Canada** include the federal Strategic Innovation Fund and Clean Fuel Standards, alongside provincial efforts including Alberta's Technology Innovation and Emissions Reduction regulation that covers industrial greenhouse gas emissions through an emissions trading system.
- **Germany** announced in 2021 a subsidy programme aimed at supporting the country's raw material industry in developing technologies for CCUS.
- **Australia** expanded in 2020 the remits of the Clean Energy Finance Corporation and the Australian Renewable Energy Agency to include CCUS. In addition, they launched in 2021 a Carbon Capture Use and Storage Development Fund for pilot or pre-commercial projects aimed at reducing emisons.

1 IPCC, Global Warming of 1.5°C
2 IEA, The Role of CO_2 Storage, 2019
3 GCCSI, Global Status of CCS 2020
4 International Energy Agency, CCUS in Clean Energy Transitions, 2020

The potential of CCUS in Saudi Arabia

Saudi Arabia already has extensive expertise across the CCUS value chain, with two CCUS projects in operation and a high level of international collaboration on CCUS:

- Aramco's **Uthmaniyah demonstration project uses carbon dioxide for enhanced oil recovery** (EOR) injection. The project has the capacity to capture 0.8 million tonnes of carbon dioxide per year from the Hawiyah natural gas plant and transport it through 85 km pipeline for injection in the Uthmaniyah field.

- SABIC has a **carbon utilization project, aimed at enhanced chemicals production.** The project captures 0.5 million tonnes of carbon dioxide per year from an ethylene glycol plant and utilizes it to produce methanol and urea fertilizers.

- Saudi Arabia is a leading member in **international CCUS collaborations** such as the Clean Energy Ministerial CCUS initiative[5], the Carbon Sequestration Leadership Forum, and Mission Innovation Carbon Capture Challenge, driving research, technology and policy development for CCUS scale-up.

Leveraging public and private sector support to scale up deployment through CCUS hubs could help Saudi Arabia become a low carbon economy, capturing millions of tonnes of carbon dioxide emissions across the industry and power sectors, while building an export market in low carbon hydrogen and industrial products.

Domestic energy consumption and greenhouse gas emissions have been rising rapidly in the country over the past decades, due to economic growth and industrial capacity expansion. Policies to improve energy efficiency and deploy renewables are beginning to slow emissions growth, but without concerted action greenhouse gas emissions would certainly continue to increase due to the importance of oil and gas in the Saudi economy.

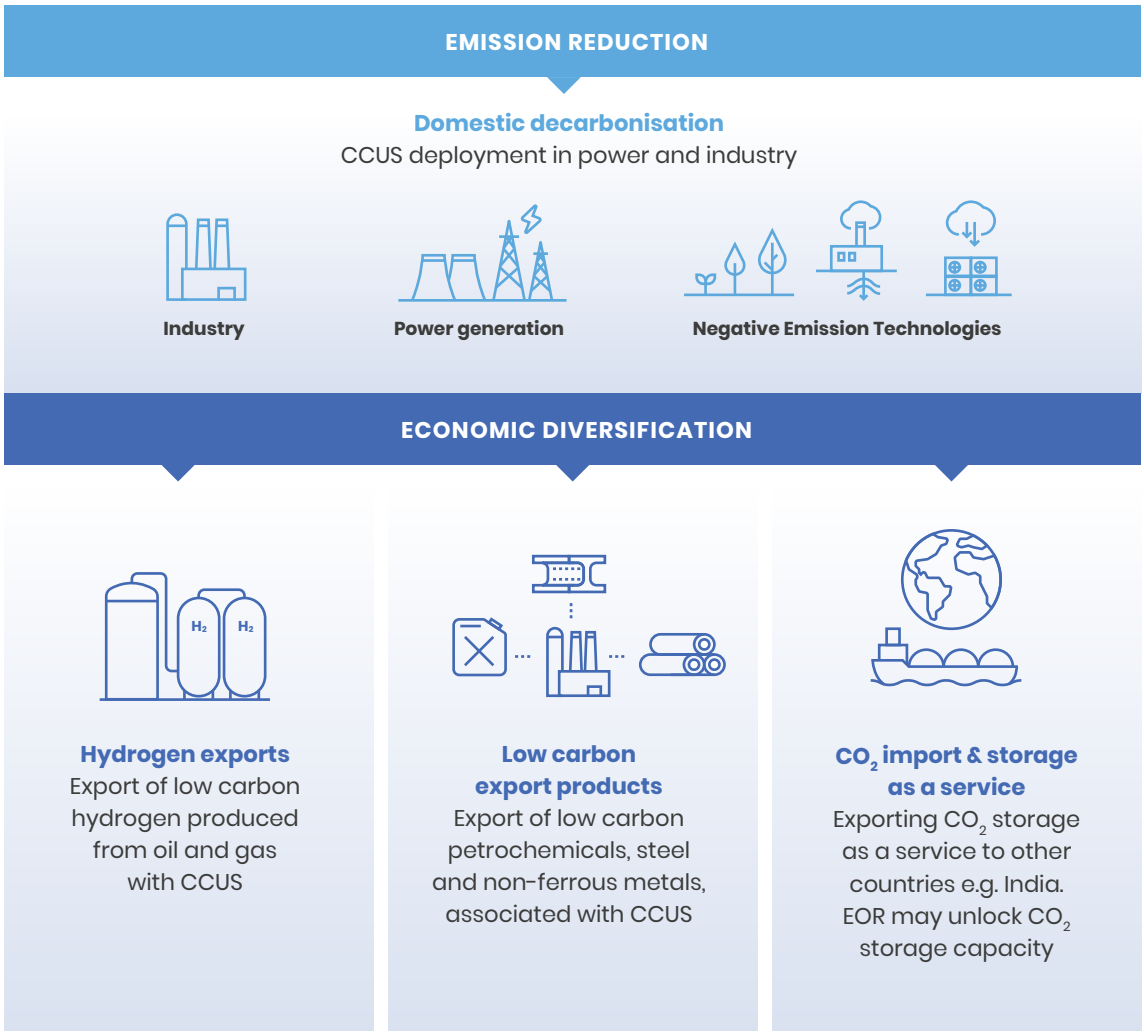
Alongside climate benefits, CCUS has the potential to support several key aims in Saudi Arabia's Vision 2030, such as economic diversification, job creation and sustainable development. Saudi Arabia is currently heavily dependent on oil and gas exports to support its economy, and Vision 2030 includes a clear ambition to diversify the economy, highlighting opportunities to leverage expertise in oil and petrochemicals to invest in the development of adjacent supporting sectors.

As Saudi Arabia works towards implementing its circular carbon economy approach, bringing together all parts of the energy system value chain within one low carbon framework, CCUS would help protect existing high value jobs and unlock significant future opportunities, including the export of clean hydrogen and additional low carbon products such as petrochemicals or steel.

Saudi Arabia could also opt to develop carbon dioxide storage resources to provide storage as a service to other countries that want to decarbonize their industrial sectors, but do not have suitable storage capacity.

5 The CEM CCUS initiative brings together energy ministers from 11 countries. OGCI and CEM signed a joint agreement on accelerating the CCUS industry in 2019.

Figure 1: Key values unlocked for Saudi Arabia by CCUS



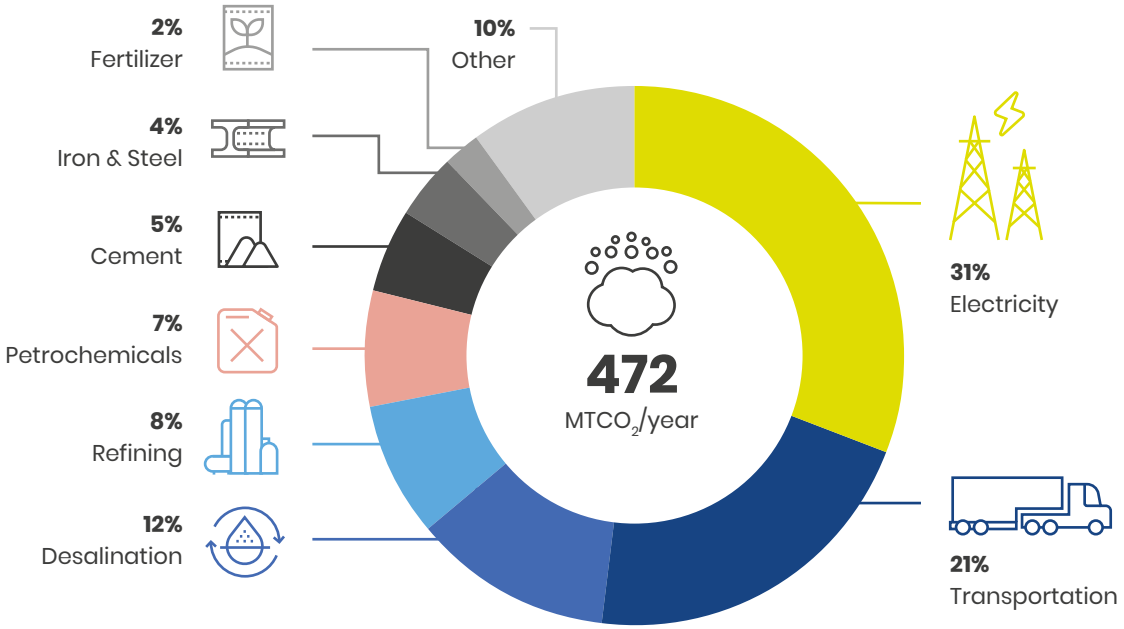
2.
How CCUS can help to decarbonize the Saudi Arabian economy

Carbon dioxide emission sources

The industry and power sector comprised around three-quarters of Saudi Arabia's total carbon dioxide emissions, with the rest largely coming from transport. Power generation and desalination account for around 45% of the total, with power sector emissions coming mostly from oil and gas fired units. Industry – predominantly refineries, petrochemicals, cement, iron and steel – contributes 33% of the total.

Both power generation and industry offer significant potential for direct CCUS application; the transport sector can decarbonize through other technologies and fuels, some of which (including hydrogen) rely on CCUS indirectly.

Figure 2: CO_2 emissions in Saudi Arabia by sector in 2015



Source: Third communication of Saudi Arabia to UNFCC

An ecosystem of policies/regulations, storage appraisals and demonstration/deployment projects are required to create a CCUS industry that can scale up storage capacity and drive down costs.

Appraising carbon dioxide storage resources

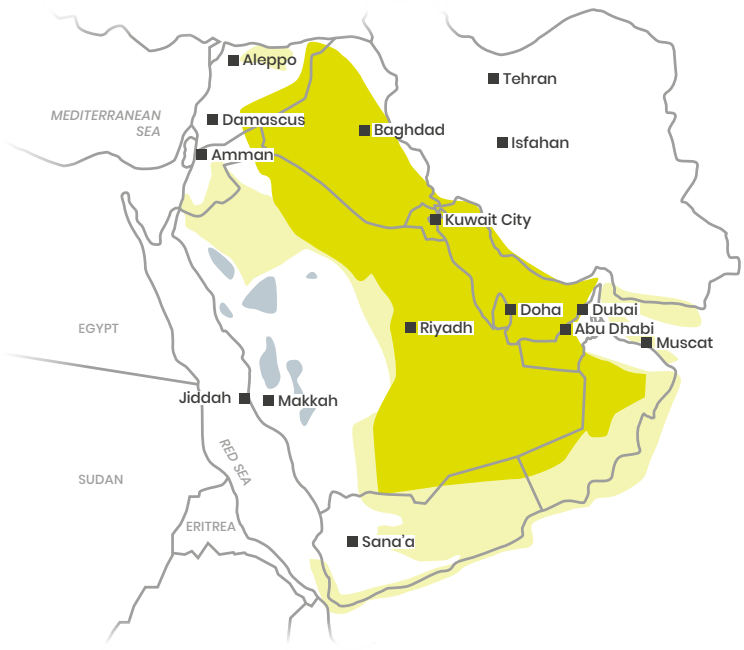
An independent overview of oil and gas fields, as well as deep saline aquifer formations, suggests that there are significant suitable storage resources available in Saudi Arabia in locations that are close to concentrations of emission sources. As for many countries around the world, however, the Kingdom's carbon dioxide storage potential is uncertain and will require site-specific appraisal studies to substantiate the potential.

Realizing the value offered by CCUS hubs in Saudi Arabia, therefore, will require further storage resource appraisal (such as seismic data gathering, well drilling and testing, and reservoir performance modelling). Evaluating the specific infrastructure required to collect, transport and storage carbon dioxide from multiple sources will also require a series of feasibility and front-end engineering design (FEED) studies to prepare the way for investment decisions.

Figure 3: CO_2 storage resources in Saudi Arabia by suitability and type

Geological storage suitability

- Highly suitable, sedimentary basins or continental margins
- Possible, sedimentary basins or continental margins
- Unproven, extrusive volcanic basalt



Source: UNIDO, Global Industrial CCS Technology Roadmap, 2011

Developing business models for CCUS

Scaling up CCUS requires the development and implementation of CCUS funding mechanisms. Given barriers to the commercialization of CCUS, government and the private sector will need to contract and procure the first CCUS projects. Over the longer term, economic reforms and other measures could unlock the potential for market mechanisms to deliver CCUS cost-effectively.

Effective market mechanisms in Saudi Arabia could include:

- **obligations with CCS certificates** by which emitters are obligated by law to ensure a certain amount of carbon dioxide is captured and stored. Certificates are awarded for storage and can be used to meet the obligation and traded freely.
- **emission performance standards with CCS certificates** which set minimum emission standards by which emitters must abide. The tradeable certificates function similarly to the obligation scheme and can be used to meet the standard.
- **tradable tax credits** which are reductions in the tax liability of firms if they perform CCUS. Credits can be provided for stored carbon but also for capital investment.
- **public procurement** which entails the government directly procuring CCUS.

International carbon dioxide trading and accounting mechanisms will be crucial to enable carbon dioxide storage as a service, and to unlock the full potential for negative emissions technologies (NETs) and other carbon removal approaches, such as direct air capture, mineralization and nature-based solutions.

Deployment, research, development and demonstration

Scaling up CCUS deployment in Saudi Arabia will be underpinned by global CCUS technical and commercial knowledge, as well as by getting new projects into operation. The roll-out trajectory for each industrial sector depends on application maturity, technical challenges and cost. CCUS in the petrochemicals, electricity, ammonia and fertilizer industries are likely to follow a faster deployment curve, while cement and refining could be slower due to higher complexity.

Boosting investment in research, development and demonstration (RD&D) activities will also be needed, for example research on utilization options and progress in hydrogen production technologies. A targeted RD&D programme, involving government, universities and industry, could accelerate the market readiness and lower the cost of CCUS technologies.

Further CCUS opportunities: utilization and removals

Carbon capture and utilization (CCU) applications and negative emission technologies (NETs) present additional long-term opportunities for Saudi Arabia to unlock the value of CCUS, especially within the framework of the Circular Carbon Economy.

Carbon dioxide can be used in several applications or can be transformed – biologically or chemically – into new products. Utilization can provide a cost-effective way to use captured emissions and produce new commodities, helping to decrease the carbon footprint of industry, fuels or building materials. At the same time, if economic applications are developed, they can support CCUS through providing a value for the carbon dioxide captured. Some CCU applications can be integrated into a future energy system by using renewables to power a carbon dioxide to useful products value chain, providing system benefits.

While most CCU applications are currently immature and small scale, they may develop to be economic and significant in the longer term. In Saudi Arabia, there are several opportunities for carbon dioxide utilization, some of which are already being developed. These CCU applications can be grouped into three categories:

- **Carbonate production**, converting highly saline brine from desalination into sodium bicarbonate and soda ash. This is an attractive option specifically for integrated co-generation power and desalination plants as it combines the treatment of two industrial waste streams – sodium and carbon dioxide – with the generation of two industrial products.

- **Synthetic fuels** are an alternative option to decarbonize challenging sectors, such as shipping and aviation. These carbon neutral fuels are still in the early stages of development. To be competitive, they currently require a carbon value of around $250/tCO_2$, as well as ultra-low-carbon electricity.

- **Mineralization** offers permanent carbon dioxide storage through industrial waste carbonation. For example, iron and steel slag carbonationcan be used to produce green construction materials.

Carbon dioxide removals

NETs remove carbon dioxide from the atmosphere – with approaches such as biomass (BECCS) and direct air capture (DACCS) relying on CCUS infrastructure to transport and store the carbon dioxide[6]. As these technologies develop, they may become a cost-effective way to offset emissions from some sectors, balancing remaining emissions from fossil fuels with removals to meet climate goals. Many NETs, such as direct air capture and mineral carbonation, are emerging technologies, where cost reductions and support to lower costs are needed before large-scale implementation is economically attractive. They provide, however, an option for offsetting emissions in hard-to-decarbonize sectors, such as aviation and shipping. They could also become a potential revenue stream for Saudi Arabia, if international trading of carbon offset credits is regulated and facilitated through Article 6 of the Paris Agreement.

6 International Energy Agency, CCUS in Clean Energy Transitions, 2020

3.
CCUS and the development of low-carbon exports

CCUS and export potential

As a broad range of countries and companies raise their climate ambition and targets, CCUS opens up interesting new business opportunities to build competitive advantage as an exporter of low carbon products on a global scale. In petrochemicals, CCUS-enabled low carbon products could ensure that Saudi Arabia maintains and builds on its existing market share. In areas such as iron and steel and non-ferrous metals, hydrogen and storage services, CCUS could help open up new markets, driving future-oriented diversification.

Export of low carbon goods from energy intensive industries
In most countries, the cost of decarbonizing energy intensive industries will be significant. As the price of carbon gets factored into energy intensive products, countries which can cheaply produce low carbon products can gain a competitive advantage. Given Saudi Arabia's low cost of energy, and potential for relatively low cost CCUS, it could become a major global manufacturer of low carbon energy intensive products in petrochemicals, iron and steel and aluminium.

Large-scale hydrogen production and exports
Global low carbon hydrogen demand is expected to grow significantly over time, driven by fuel-switching corporate strategies to reduce greenhouse gas emission profiles to align with climate ambitions. Saudi Arabia already produces significant volumes of hydrogen to supply its domestic refining industry. This industry can act as a strong anchor to scale up blue hydrogen production (production of hydrogen through fossil fuels, with emissions captured through CCUS) in Saudi Arabia. While there is significant uncertainty around future market dynamics, Saudi Arabia is well placed to be a competitive player. Hydrogen production costs are heavily dependent on energy cost, and there are well-established shipping trading routes to Europe and Southeast Asia.

Provision of carbon dioxide storage as a service
Saudi Arabia could be well placed to provide carbon dioxide transport and storage services for countries where demand for storage exceeds supply – whether due to geology, CCUS infrastructure or politics.

ARAMCO DEMONSTRATES A NEW LOW CARBON VALUE CHAIN

In September 2020, Aramco, SABIC and Japan's Institute of Energy Economics successfully demonstrated the production and shipment of 40 tonnes of high-grade low carbon ammonia from Saudi Arabia to Japan for use in zero carbon power generation.

The value chain began with the conversion of hydrocarbons to hydrogen and then to ammonia. The associated carbon dioxide emissions were captured during the process and transported for utilization in two different locations: for methanol production at SABIC's Ibn-Sina facility and for enhanced oil recovery at Aramco's Uthmaniyah field.

Such multinational partnerships will be key in realizing the circular carbon economy championed by the Saudi Arabian G20 presidency.

4.
Potential CCUS hubs in Saudi Arabia

Identifying Saudi Arabia's potential hubs

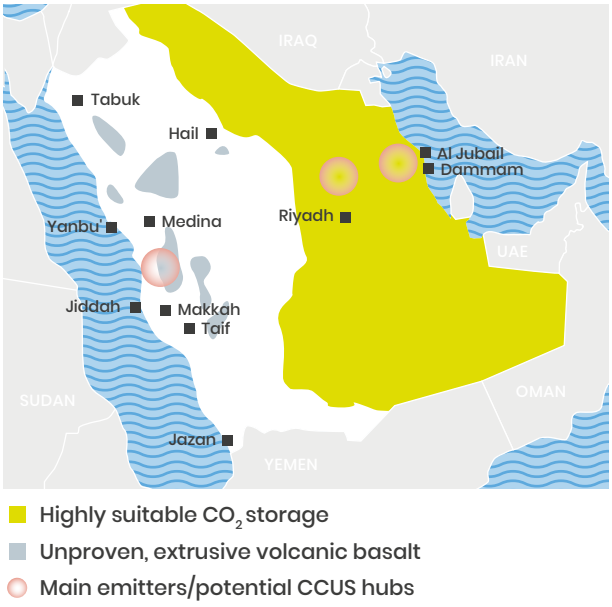
Saudi Arabia's major carbon dioxide emitters are focused in three areas, providing a significant opportunity for multiple CCUS hubs to realize economies of scale.

The Eastern region (comprising Dammam and Jubail) has the most diverse cross-sectoral profile of industries, with representation from power and all industrial sectors. The region has potentially suitable storage resources.

The Central region (around Riyadh) is dominated by power generation, but includes other industries, such as cement, refining, and iron and steel. It also has potential suitable storage.

The Western region (Jiddah, Yanbu') is relatively diverse and lies partly on basaltic formations that could be developed.

Figure 4: Map of potential CCUS hub locations in Saudi Arabia



Source: adapted from UNIDO, Global Industrial CCS Technology Roadmap, 2011 and OGCI analysis

WHAT IS A CCUS HUB?

- Multiple industrial point sources of carbon dioxide connected to a carbon dioxide transport and storage network.
- Access to large geological storage resources with the capacity to safely and permanently store carbon dioxide from industrial sources for decades.
- Economies of scale to deliver lower unit costs for carbon dioxide storage.
- Synergies reduce cross-chain risks and support commercial viability.
- CCUS infrastructure supports existing industries, attracts new clean industries and enables innovation utilization and negative emissions technologies.

CCUS collaboration in the Gulf

There is also potential for large-scale roll-out and interconnection of hubs in the **Gulf countries**. In addition to Saudi Arabia's experience, the Gulf region has leading expertise in the demonstration of CCUS projects. The **UAE**, for example, has the world's only CCUS steel facility, developed by ADNOC and Masdar. **Qatar** recently commissioned a CCUS facility that can store 2.5 million tonnes of carbon dioxide a year from its expanding liquefied natural gas production.

In addition, the Gulf region has several factors that could facilitate a cross-border hub. Most power generation plants are fossil-fuel based and the heavy energy-intensive industries tend to be concentrated in a few locations enabling economies of scale for CCUS. At the same time, the region is rich in high quality carbon dioxide storage capacity. As in Saudi Arabia, low energy costs enable potential low manufacturing costs to facilitate low carbon exports. Existing experience of CCUS operations could help accelerate deployment, as local stakeholders have knowledge of what is required.

5.
CCUS and the Circular Carbon Economy in Saudi Arabia

Realizing the circular carbon economy

Climate change has become the most pressing global issue of our time, requiring a global response that bring together all solutions and efforts for reducing greenhouse gas emissions to the atmosphere. Mitigation efforts need the combination of improved energy efficiency, the provision of clean and affordable energy, as well as carbon recycling, storage and removal.

CCUS technologies play a key role for two reasons: first, they needed to accelerate the decarbonization of existing hard to abate sectors that lack alternative mitigation solutions, and secondly, these technologies will be crucial to removing emissions from the atmosphere, in order to achieve emissions neutrality.

To overcome these challenges, Saudi Arabia has promoted and secured endorsement of the circular carbon economy approach by G20 leaders during its presidency of the G20 in 2020. This approach is consistent with OGCI's circular carbon model. It values all solutions and encourages all efforts to mitigate greenhouse gas emissions through a closed loop involving 4Rs: reduce, reuse, recycle, and remove. Alongside renewables, energy efficiency, nuclear power, and natural climate solutions, CCUS is key to the circular carbon economy approach, since it can contribute to reducing, reusing, recycling, and removing emissions across key economic sectors.

Saudi Arabia could play a leading global role in CCUS development and deployment. Not only can it leverage its low cost of oil and gas production and renewable energy, combined with its potential storage resources to capture millions of tonnes of carbon dioxide per year. It can also use CCUS to enable its own energy transition, building a low carbon product export industry and contributing to the realization of the circular carbon economy vision.

OIL AND GAS CLIMATE INITIATIVE

WHAT IS THE OIL AND GAS CLIMATE INITIATIVE?

The OGCI is a CEO-led initiative that aims to accelerate the industry response to climate change. OGCI member companies explicitly support the Paris Agreement and its aims.
As leaders in the industry, accounting for almost 30% of global operated oil and gas production, we aim to leverage our collective strength and expand the pace and scope of our transitions to a low-carbon future, so helping to achieve net zero emissions as early as possible.

Our members collectively invest over $7B each year in low carbon solutions. OGCI Climate Investments was set up by members to catalyze low carbon ecosystems. This $1B+ fund invests in technologies and projects that accelerate decarbonization in oil and gas, industry and commercial transport.

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OUR MEMBER COMPANIES

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