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The Potential Value of CCUS Deployment towards Low Emissions Pathway (Policy Brief)

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1. Introduction

Addressing climate change impacts is a challenge to all sectors, in particular hard-to-abate sectors. It requires meaningful reductions and/or avoidance of CO_2 emissions from such sectors as they will continue to exist way into the 21st century. Cognizant of their important role in ensuring sustainable development; it is critical to examine the role of negative emissions technologies towards low emissions pathway. The Carbon Capture Utilization and Storage (CCUS) is one of the most developed and matured technologies in this area compared to other alternatives, and demonstrates great potential in decarbonizing hard-to-abate sectors. With countries and companies making aggressive emission reduction pledges, interest in CCUS will continue growing to help meet committed targets.

This policy brief presents a literature review on the following areas: (1) the value of deploying CCUS in Saudi Arabia, (2) the role CCUS has in low carbon transitions, (3) the measures taken by countries to promote CCUS, (4) the potential of deploying CCUS in oil & gas producing countries, and (5) the financial challenges facing the wide-scale adoption of the technology. Finally, the paper ends up with a set of recommendations on policy tools to enable large scale investments in CCUS.

2. Literature Review

Reducing CO_2 emissions drastically will require the participation of hard-to-abate sectors, as well as heavy transport such as heavy-duty road transport, marine and aviation sectors. Combined, these comprise a total of 37% of CO_2 emissions (IEA 2019a, 2019b, 2019c 2019d). The Intergovernmental Panel on Climate Change (IPCC) models show that reaching the 1.5 °C or 2 °C temperature goals cannot be achieved without first reaching emission neutrality, coupled with significantly ramped up efforts to deploy and use negative emission technologies. In turn, these goals cannot be achieved without moving hard-to-abate sectors towards sustainability. (McDonough n.d.) (**1**)

Scaling up CCUS is an essential tool to achieve these goals. 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. (OGCI 2021) (2)

CCUS and the Circular Carbon Economy

The Saudi G20 presidency championed the concept of the Circular Carbon Economy (CCE) for achieving climate global goals, which values all options and encourages all efforts to mitigate carbon accumulation in the atmosphere. The CCE approach stems from the circular economy or the circularity concept, which is an alternative to the traditional linear economy of make, use, and dispose (McDonough 2020). Specifically, it maximizes the values of materials, products, and processes, while minimizing costs and wastes based on the famous 3Rs—reduce, reuse, and recycle—giving rise to new ways of designing, using, and disposing, such as “cradle-to-cradle” (McDonough and Braungart 2010). The CCE approach adds the carbon dimension to circularity to reduce carbon emissions through the efficient use and utilization of energy, materials, and processes in the economy. Adding a fourth R to the 3Rs of circularity yields the following approach: reduce, reuse, recycle, and remove carbon/GHGs (Williams 2019; Al Khowaiter and Mufti 2020). (United Nations 2017) (see figure 1) (3)

A portfolio of carbon management technologies could essentially facilitate limitation of rising atmospheric CO_2 concentrations. Carbon Capture and Storage (CCS) and CCUS are two key methods for carbon or specifically CO_2 management in energy and emission intensive industries, processes and operations. Thus, CCS and CCUS integrated with fossil-fueled energy and other industrial processes could limit temperature well below 2°C by 2100 while meeting increasing global energy demand. Building on current CCS and CCUS’s development and deployment, modelling has been carried out in order to assess the future potential contribution of CCS and CCUS in reducing emissions of CO_2 from economic activities. In fact, CCS has the capacity to enhance the sustainability of the global energy system and is projected to achieve 14% cumulative reduction of CO_2 emissions by 2050. Modelling of global climate change mitigation indicates limiting 450 parts per million (ppm) CO_2-eq concentration by 2100 in the absence of CCS is problematic according to IPCC 5th Assessment Report. Introducing CCS and CCUS in fossil fuel-based energy and industrial facilities could substantially reduce CO_2 emissions by the end of 2100. In fact, the share of low-carbon electricity supply could increase from the current share of approximately 30% to more than 80% by 2050, with fossil fuel power generation without CCS phased out almost entirely by 2100. Application of CO_2 capture processes in industrial facilities can be more effective and can lead to competitive cost of the CO_2 avoided with respect to power plants. (Mnasouri N 2020) (4).

Reduce	Reuse	Recycle	Removed
Reducing the amount of carbon entering the system	Reusing carbon without chemical conversion	Recycling carbon with chemical conversion	Removing carbon from the system
• Energy and materials efficiency • Renewable energy, including hybrid use with fossil fuel • Nuclear energy, including hybrid use with fossil fuel • Advanced ultra-super-critical technologies for coal power plants • Hydrogen (blue/green) fuel cells for long-distance heavy-duty vehicles • Ammonia produced from zero-carbon hydrogen (blue/green) for power generation and ships • Direct reduction in steel making by using CO_2 free hydrogen (blue/green)	• Carbon capture and utilization (CCU) • Use CO_2 at carbon utilization facilities, such as at greenhouses for enhancing crops • Bio-jet fuels with reed beds • Algal synthesis	• CCU • Artificial photosynthesis • Bioenergy recycle in the pulp and paper industry • Bioenergy with carbon capture and storage • Carbamide (urea production using CO_2 as feedstock) • Coal ash concrete curing with absorbing CO_2 • Electrochemical reduction of CO_2 • Fine chemicals with innovative manufacturing processes and carbon recycling • Fischer-Tropsch exothermic of carbon dioxide with hydrogen syngas • Hydrogenation to formic acid • Oil sludge pyrolysis • Sabatier synthesis (CO_2 methanation: exothermic of carbon dioxide with blue/green hydrogen) • Thermal pyrolysis	• CCS • Direct air capture (DAC) • Carbon dioxide removal • Fossil fuels-based blue hydrogen

Figure 1: Portfolio of Carbon Management Technology Options across the 4Rs of the CCE Approach
Source: Redrawn from data provided by the WTO Secretariat, Geneva (Fig 5, Roy 2011). (5)

Barriers for CCUS deployment

The absence of value attached to CO_2 emissions reduction is a one of major barriers to CCUS deployment today in many regions. As such, there may be no commercial driver for industrial or power facilities to capture CO_2 as an alternative to emitting it, even where this can be done at relatively low cost. Placing a value on reducing or avoiding emissions does not necessarily require explicit carbon pricing through emissions trading or explicit taxation of emissions; though these policy measures can play an important role. It can also take the form of public procurement programs that favor lower-emissions commodities or products, or tax credits associated with CO_2 storage. (International Energy Agency 2020) (6)

Financial barriers are reflected by costs, pricing, and funding. The capital costs for proofs-of-concepts and other testing actions are noticed as very high in the field of CO_2 utilization. In addition, new CO_2 utilization ventures report to be often incapable of either scaling down at capital expenditure rates that would enable technological applications or building the facilities large enough to make the capital expenditure feasible, because raw materials are not available in sufficient quantities. Furthermore, their pricing capabilities are limited and they are unable to compete on under-market (dumping) prices. Funding opportunities and cost or availability of inputs such as CO_2 and energy were stated to vary from one geographic location to another (see also Hendriks et al., 2013). Moreover, it is the experience of CO_2 utilization ventures that the availability of funding sources is limited and that the exploitation of these sources is also challenging in terms of administration. (Kant 2017) (7)

Delays in investment and innovation in CCUS technologies would have a lasting impact on future emissions trajectories and affect the pace at which net-zero emissions can be achieved. The IEA calculates that a five-year delay in completing demonstration projects for pre-commercial CCUS technologies, together with a slowdown in the deployment of CCUS technologies at early adoption stage, would result in 50% less CO_2 emissions being captured worldwide in 2030 and 35% less in 2040 than in the Sustainable Development Scenario (IEA, 2020). CO_2 captured from cement production and power generation would be the areas most affected, accounting for almost 80% of the reduction in CCUS deployment through to 2040. The delay in deploying CO_2 capture technologies would also hold up the rate of decline in costs over time, due to the missed opportunity for learning-by-doing. (International Energy Agency 2020) (6)

Bringing forth the investment needed to deploy CCUS on the scale envisioned in the Sustainable Development Scenario requires measures to make such investment commercially attractive. An estimated USD 160 billion of cumulative investment in CCUS is needed to 2030 in that scenario, a tenfold increase from the decade to 2020. While a range of specific policy measures could be employed to support this investment depending on national circumstances or preferences, their overall effectiveness would be improved by three key approaches: placing a value on emissions reductions, provide funding to support capital and operating costs, and allocating risks between the public and private sector. (International Energy Agency 2020) (6)

CCUS value and opportunities for deployment

Creating CCUS-enabled industrial hubs to leverage economies of scale and drive down costs through accelerated deployment. CCUS technology is required globally to meet the Paris Agreement climate goals in a cost-effective manner. In the IPCC scenarios, an average of 13 gigatons of carbon dioxide needs to be captured annually by 2060 to keep global warming below 1.5°C below pre-industrial levels. 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. Currently, around 20 large-scale CCUS projects store around 45 million tons globally per year. 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 realization 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. (OGCI 2021) (2)

The next decade will be critical to the prospects for CCUS and for putting the global energy system on a path to net-zero emissions. A significant scale-up of deployment is needed to provide the momentum for further technological progress, cost reductions and more widespread application in the longer term. Without a sharp acceleration in CCUS innovation and deployment over the next few years, meeting net-zero emissions targets will be all but impossible. (International Energy Agency 2020) (6)

Countries taking concrete policy measures to scale up CCUS Deployment

The response to the Covid-19 crisis has driven the world into a deep recession, which will almost certainly affect investment plans for CCUS. The slump in economic activity is likely to curb interest in new CCUS projects, at least in the near term, but this could be partially or wholly offset by fresh government incentives for CCUS and other clean energy technologies as part of economic recovery programs currently under development. (International Energy Agency 2020) (6)

The inclusion of CCUS in economic recovery plans and programs could help ensure that the Covid-related economic downturn does not derail recent progress in deploying the technology. A collective push by all stakeholders is needed to exploit recent progress and drive a major leap forward in deployment. Governments have a key role to play in incentivizing investment, as well as coordinating and underwriting new transport and storage infrastructure. The development of economic stimulus packages presents a critical window of opportunity for governments to support investment in a technology that will be needed to meet their climate goals. The IEA Sustainable Recovery Plan identified boosting innovation in CCUS and other crucial technologies, including hydrogen, batteries and small modular nuclear reactors, as one of six key objectives for economic stimulus packages. (International Energy Agency 2020) (6)

A new report by the Global CCS Institute notes the addition of 71 new CCS projects globally in the first nine months of 2021, bringing the total to 135. The institute reported than 41 of the 71 new projects announced were in North America and 25 in Europe. Growth in net-zero pledges and enabling policies and regulations in the US and Europe has propelled a sharp rise in projects. North America tops the CCS total project list with 16 facilities in operation and 60 under development; the EU has three operating facilities and a pipeline of 35. Roughly 10% of global installed CCS capacity is in the GCC with three facilities in the region – UAE, Qatar and Saudi Arabia. (Global CCS Institute Report 2021) **(**8)

A number of planned projects could benefit quickly from economic stimulus packages, bringing major economic, social and environmental benefits. In Europe, the Norway Longship CCS project (including Northern Lights) is expected to generate as many as 4, 000 jobs during the investment and construction phase, and 170 permanent jobs (Northern Lights PCI, 2020). In July, the European Free Trade Association (EFTA) Surveillance Authority cleared the way for the Norwegian government's support for the project under EU market rules, recognizing it as "a ground-breaking step towards tackling climate change" (ESA, 2020). (International Energy Agency 2020) (6)

The employment benefits of encouraging these projects – a major objective of stimulus packages – could be significant. At least 1, 200 direct construction jobs could be created at each new large-scale capture facility, rising to 4, 000 or more depending on location, application and size. CCUS investments would also secure existing jobs and minimize social and economic disruption by enabling the continued operation of power and industrial facilities under tighter emissions constraints. For example, the developers of the Net Zero Teesside industrial hub claim that CCUS infrastructure could safeguard between 35% and 70% of existing manufacturing jobs in the region (Net Zero Teesside, 2020). (International Energy Agency 2020) (6)

Many of the job opportunities that will arise in the CCUS sector will also be able to make use of the subsurface skills and experience of personnel in the oil and gas sector, which has seen thousands of job losses already in 2020. These opportunities include the near-term employment needs associated with CO2 storage exploration, as well as the more intensive phase of characterization and development of new storage facilities. (International Energy Agency 2020) (6)

The potential of CCUS in Oil and Gas Producing Countries

Oil and gas exporters could pursue policies to increase the resilience of their core energy sector in a world transitioning to net-zero emissions by competing on reducing emissions. Technologies related to geological storage of CO2 could play a key role in these countries' near-and longer-term, low-emissions development strategies. Carbon Capture, Use and Storage (CCUS) is a climate mitigation action through which some oil and gas exporters could establish a competitive advantage given their natural (e. g. geological storage capacities, depleted hydrocarbon reservoirs, existing infrastructure) and technical resources (e. g. the expertise in subsurface technology). Also, the deployment of CCUS could provide oil and gas exporters with an opportunity to continue to monetize their reserves. (Bassam Fattouh 2021) (9)

Several Middle Eastern countries have set ambitious renewable energy targets to be reached by 2030 and 2050, while also committing to reducing emissions from the hydrocarbon industry. In 2021, Saudi Arabia announced the Saudi Green Initiative (SGI) and Middle East Green Initiative (MEGI), their scope covers a spectrum of climate and energy-related plans aimed at addressing both economic and environment developments and illustrates the need to take a "whole systems" approach in tackling societal and environmental issues. Furthermore, the concept of CCE is gaining traction, though cost is still preventing large-scale implementation of technologies to extract, store and utilize carbon dioxide in the effort to decarbonize the energy and industrial sectors. Saudi Arabia and the UAE have some of the largest CCS and CCUS projects in the world, with the Uthmaniyah facility in Saudi Arabia and Reyadah in the UAE capturing each around 800, 000 mt/year of CO2, used mainly for enhanced oil recovery (EOR), and potentially to produce blue hydrogen. (World Energy Council 2021) (10)

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 tons of carbon dioxide a year from its expanding liquefied natural gas production. (OGCI 2021) (**2**)

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. (OGCI 2021) (2)

Policy tools that enable large scale investments in CCUS

The key recommendations outlined below indicate the role of policy measures for CCUS to create sustainability pathways towards carbon-neutral hydrocarbons for the mitigation of CO_2 and the costs incurred by oil-based countries and industries to attain the low emission pathway.

1. Developing business models/Public Private Strategy 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.
2. 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. CCU applications can be integrated into a future energy system by using renewables to power a carbon dioxide to useful products value chain, for example Turbines powered with Hydrogen from hydrocarbons. Boosting investment hydrogen production technologies research, development and demonstration (RD&D) activities
3. Institutionalize and incentivize heavy industry and corporate-wide initiatives to manage emissions towards achieving climate goals/Carbon Trading Market/Voluntary Carbon Market. This can be achieved by utilizing and upscaling existing schemes and creating new policy tools for carbon circularity in the hydrocarbon industry across the value chain. Guide mapping for high-priority technologies to be targeted for financing would help align the technology investments by the governments
4. Provide a platform for cooperation among nations and consolidate efforts to manage emissions in hard-to-abate industries/CCUS hubs. This approach would require companies and governments to emphasize the need to

deploy at scale and rapidly, as well as to ensure institutional sustainability. The latter provides powerful institutional structures and good governance principles for carbon-neutralization efforts sustainable in the long run.

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