CHAPTER 2: CARBON CAPTURE AND STORAGE

INTRODUCTION

This chapter provides an assessment of the role of carbon capture and storage (CCS) in Qatar and other Gulf Cooperation Council (GCC) countries; barriers to developing this technology; existing initiatives taking place at the international level; bilateral and regional cooperation on CCS; and action on CCS in Qatar and the region. The chapter concludes with recommendations as to how Qatar can develop a national CCS program that helps address challenges of increasing emissions growth and enhances enhances Qatar's capacity for R&D and expertise on CCS technology.

THE ROLE OF CARBON CAPTURE AND STORAGE (CCS)

The Role of CCS in Reducing Emissions

Fossil fuels are presently the dominant source of global primary energy demand and will likely remain so for the foreseeable future.[94] The purpose of carbon capture and storage (CCS) is to enable the continued use of fossil fuels while reducing CO_2 emissions, thereby reducing the climate impact of fossil fuel use. As fossil fuels currently supply over 85 percent of all primary energy globally, stabilizing global temperatures at or near the 2°C warming target will require CCS to make a significant contribution to reducing GHG emissions.[95]

In the power sector, CCS has the potential to deliver large reductions in emissions over the next century while still allowing for extensive use of fossil fuels such as coal or natural gas in the electricity generation mix. In the industrial sector, the potential for CCS is also significant, particularly if the technology can be successfully applied at scale to carbon-intensive fuel production such as gas-to-liquids (GTL) and liquid natural gas (LNG) processes. The potential for combining CCS with enhanced oil and gas recovery helps make CCS economically viable.

According to the IEA's Energy Technology Perspectives 2012 2°C scenario, CCS contributes to one-sixth of CO_2 emission reductions required by 2050, and 14 percent of the cumulative emissions reductions between 2015 and 2050 compared to a business-as-usual approach, which would lead to a 6°C rise in average global temperature.[96] However, despite its promise, CCS faces significant technological, financial and regulatory obstacles.

The Role of CCS in Qatar and the GCC Region

Qatar is one of the world's largest per capita emitters, with the bulk of emissions generated by the energy sector (96.5 percent). Almost half of energy-related emissions comes from electricity and heat production from gas-fired electricity generators, and industrial processes are the second largest source of GHG emissions in Qatar.[97] Qatar has the world's third largest natural gas reserves, and its proven reserves of oil were the 13th largest in the world at the end of 2012. The oil and gas sector accounted for 58 percent of Qatar's 2011 GDP. Qatar relies entirely on oil and natural gas for its energy needs, and its GHG emissions will continue to increase as a result of increased production and expanded operations in the oil and gas sector.[98]

GCC countries hold 30 percent of the world's proven oil reserves and 23 percent of the world's proven gas reserves,[99] and their economies are closely linked to the exploitation of these hydrocarbons. Oil and gas exports from this region are expected to remain in high demand around the globe for the foreseeable future. The GCC countries have experienced a surge in domestic energy demand accompanying the growth in consumption levels stemming from rising populations and economic expansion. Energy consumption in the GCC region has grown, on average, 4.5 percent between 2011 and 2012[100] and 74 percent since 2000, and is projected to be nearly double current levels by 2020.[101] A detailed breakdown of the energy mix for Qatar and the GCC is provided in Chapter 1.

CCS has the technical potential to help Qatar and other GCC countries maintain their hydrocarbon-driven economic activity while mitigating the negative effects of increased CO_2 emissions. Additionally and equally significant, developing a commercial CCS operation in Qatar would be an important step towards demonstrating its feasibility and would put Qatar at the forefront of developing a climate change technology that could be utilized globally.

Qatar and the GCC have significant financial and environmental incentives for the successful commercial development of CCS, which can be deployed for three region-specific applications: natural gas-fired power generation; enhanced recovery of oil and natural gas; and other advanced, emissions-intensive industrial processes, including GTL projects and LNG production. As a previous Brookings report has observed, the GCC also has a comparative advantage in developing CCS, given its considerable technical capacity in oil and gas drilling and conventional combustion technologies.[102]

In fact, CCS for enhanced oil recovery (EOR) is a common thread across GCC projects and represents the most compelling commercial justification for CCS. For major oil-producing countries like Qatar, combining CCS with EOR can greatly reduce the cost of oil production.[103] And in the case of net gas-importing countries, like the United Arab Emirates (UAE), CCS with EOR can liberate natural gas for domestic consumption. Carbon-for-gas substitution would enhance domestic reserves and also allow governments to avoid LNG import or gas field development costs, while also increasing energy security.[104] However, the lack of a coordinated environmental regulation regime in the GCC region to cap future carbon emissions is limiting CCS development.[105]

BARRIERS TO DEVELOPING CCS

CCS has yet to be proven in large-scale commercial applications in the power sector, which accounts for most CO_2 emissions and, therefore, offers the largest potential for CO_2 capture. Developing a commercial-scale CCS project will require addressing a range of technological, policy and legal barriers.

Technical Barriers

On the technology front, a full CCS system consists of the integration of a number of processes, including CO_2 separation, compression, transport (typically by pipeline), injection into underground reservoirs, and long-term monitoring. In certain cases, the CO_2 extracted from fossil fuels can be pumped into existing oil or gas wells to improve production. Many of these processes are already operated commercially and at scale in the oil and gas sector.

For instance, technical barriers arise from the separation and capture of CO_2. CO_2 capture depends on the way that CO_2 is produced and could involve additional steps or modifications to remove unwanted components from the separated CO_2 before being compressed for transport. For instance, in coal-fired electricity generation, CO_2 separation processes are less advanced and require considerable redesign of traditional processes.[106] Moreover, the separation process incurs an energy penalty, further increasing the costs of CCS.

Transportation

The transportation of CO_2 is the most technically mature step in CCS, with guidelines and lessons learned available for both onshore and offshore pipeline transport, as well as recent improvements in the technical requirements and conditions for CO_2 transport by ship. The key challenge here is developing pipelines that connect sources and sinks.[107]

If CCS is to be developed on a GCC-wide basis, a pipeline network linking countries' gas infrastructure is also needed. Steps have already been taken in Qatar and the wider GCC region to enhance connectivity of the pipeline network. For instance, Qatar has already built significant LNG export terminals; exports pipeline gas to the UAE via the Dolphin pipeline;[108] and is planning to increase the pipeline's capacity from 2 billion to 3.2 billion cubic feet per day.[109] The GCC also has plans to expand existing pipeline networks in the future, and the country announced in January 2013 $18 billion in financing over the next five years toward new pipelines and associated infrastructure, adding more than 21,000 km to its current pipe network.[110] This increased capacity could provide CO_2 transportation infrastructure that would underpin a GCC-wide approach to developing CCS.

Storage

Storage of CO_2 presents technical, legal and policy challenges. One challenge is identifying potential storage sites. The current level of efforts around the world to identify specific storage sites is insufficient for the rapid deployment of CCS. There are no incentives for industry to carry out comprehensive and costly exploration works, and governments have generally not been proactive in commissioning such investigations.[111] Developing a comprehensive map of storage potential in Qatar and the GCC would be an important step.

There remain significant technical challenges with storing CO_2.[112] These include understanding how CO_2 behaves under pressure and in different storage environments. Existing laws and regulations for oil and gas operations, for instance, could be applied or developed to address some of the issues from CO_2 storage. Yet even here, long-term liability issues associated with the leakage of CO_2 to the atmosphere and local environmental impacts are generally unresolved.[113]

Many OECD member countries have already taken the steps to review and adjust their legal frameworks to incorporate CCS. Governments are also either developing comprehensive regulatory frameworks (e.g., Alberta, Canada) or project-specific frameworks to facilitate limited demonstration while advancing development of general comprehensive frameworks (e.g., Western Australia).

Three key regulatory challenges stand out. First, in almost all jurisdictions, aspects of the way that post-closure stewardship will be addressed and liabilities managed have yet to be settled; second, the relationship between CO_2-EOR and geologic storage under regulation is a question that needs to be resolved; and third, the means by which the public can provide input into the development of regulatory frameworks and the siting of individual projects has yet to be determined.[114]

Finally, social issues to do with acceptance of CO_2 storage also need to be addressed. Experience in some EU countries such as the Netherlands, for example, has shown the extent of potential opposition to CO_2 storage near residential areas. This may be less of an issue for Qatar and the GCC where storage is available offshore or in less populated areas.

Financing

There has been significant growth in spending on CCS. Cumulative global spending between 2007 and 2012 on large-scale CCS demonstration projects reached almost $10.2 billion,[115] with $7.7 billion coming from the private sector and $2.4 billion from government grants (mainly from the United States and Canada). R&D funding from government and industry has driven a compound annual growth rate of 46 percent in CCS-related patent applications between 2006 and 2011, while over the same period $12.1 billion in public funds was made available to CCS.[116] Yet, despite this growth, funding remains a barrier. There remains a need for funding for near-term demonstration projects and for providing additional financial incentives for CCS in the medium to long term. Governments are already addressing the demonstration funding gap, as indicated by a strong increase in announcements of funding for such projects in recent years.[117] The European Union has linked CCS with its Emissions Trading Scheme by setting aside allowances for CCS project development.

Another approach to stimulate the commercialization of CCS would be with sectoral performance standards for electricity generation, mandating that some significant percentage of electricity be carbon free or meet specific performance standards. The advantage of sectoral performance standards is that they are technology-neutral—allowing the market to choose which technology to build—and they allow for a more stable investment climate for constructing the large and costly infrastructure that technology such as CCS will require.

In the U.S., for example, the Environmental Protection Agency (EPA) is developing carbon pollution standards for existing power plants by 2015,[118] and has also announced a new proposal to limit greenhouse gas emissions from new power plants. The proposed Carbon Pollution Standard for New Power Plants would "establish New Source Performance Standards (NSPS) under the Clean Air Act to limit emissions of CO_2 from coal- and natural gas-fired power plants."[119] The proposed standards for power plants, fueled by both natural gas and coal, would set an emissions limit of 1,100 pounds of CO_2 per megawatt-hour (MWh) of electricity generated by new coal-fired electric generating units (EGUs), and a standard of either 1,000 or 1,100 lbs/MWh (depending on size) for new natural gas-fired plants. Coal-fired plants would find it impossible to comply with the standard without requiring the adoption of CCS to store about 40 percent of the CO_2 they produce.[120]

However, without any economic utilization, costs for CCS are currently high relative to other greenhouse gas reducing technologies—about $62/ton to $112/ton of CO_2 avoided, as opposed to the $10-16 range for many renewable energy technologies (including onshore wind, geothermal and hydropower technologies).[121] Nevertheless, costs could be reduced substantially with an aggressive research program, and the economics of CCS will improve as nations begin to adopt carbon taxes or other carbon-pricing policies over the coming decades. CO_2 for EOR also improves the economics of CCS, as this technology offers the potential for storing significant volumes of CO_2 while increasing domestic oil production. As oil prices increase, the economic viability of CO_2-EOR improves—although costs are project-specific and vary widely based on location, the geologic characteristics of the CO_2-EOR target, the state of development/depletion of the target field, and the amount of CO_2 required. Costs are comparable to conducting secondary oil recovery operations, and incremental development costs associated with CO_2-EOR in an existing field would be substantially less than in a new development, as there is an opportunity to reduce capital costs by sharing field operating costs.[122]

CCS INITIATIVES

International Forums Working on CCS

There are a number of international forums or initiatives dedicated to advancing knowledge and capacity of CCS at the country level. These include:

- The Global Carbon Capture Utilization and Storage Summit (GCCUSS), which is aimed at addressing the progress that has been made and the challenges that need to be tackled in China and around the globe, with a mission of connecting China with global stakeholders.
- The Carbon Sequestration Leadership Forum (CSLF), an international initiative designed to facilitate the development of improved cost-effective technologies related to carbon capture, transportation and long-term storage; promote the implementation of these technologies internationally; and determine the most appropriate political and regulatory framework needed to promote CCS on a global scale. The forum is a ministerial-level organization that includes 23 member countries (Qatar is not a member of this initiative) and the European Commission.[123]
- The Global CCS Institute (GCCSI), an independent, not-for-profit company created to accelerate the development, demonstration and deployment of CCS globally through knowledge-sharing activities and fact-based influential advice and advocacy, and work to create favorable conditions for CCS implementation. With around 370 members from more than 40 countries and offices in Australia, China, France, Japan and the United States, GCCSI is a global organization with membership covering more than 80 percent of the world's carbon dioxide emissions from energy and industrial sources. Members include national governments, global corporations, small companies, environmental non-governmental organizations, research bodies and universities (Qatar is not a member).

In addition to the above examples of CCS initiatives, there are several initiatives that exist at the international level that do not focus solely on CCS, but have recently incorporated CCS into discussions. These include the UNFCCC climate change negotiations, which are facilitating a CCS needs assessments and developing rules for including CCS in the Clean Development Mechanisms (CDM). The G-8 has also been an important forum for discussing CCS issues. For example, in June 2010, the G-8's Muskoka Declaration highlighted the important role that CCS can play in helping economies transition to a low-carbon global economy, and committed to launching 20 large-scale CCS demonstration projects globally by 2010 and broad deployment of CCS by 2020 in cooperation with developing countries. In addition, the Clean Energy Ministerial (CEM) has established the Carbon Capture Use and Storage (CCUS) Action Group focused on financial commercial risks, enabling support for CCS in developing countries and industrial applications of CCS. Qatar is a party to the UNFCCC, but is not included in discussions at the G-8 or CEM.

International and Bilateral Cooperation on CCS

Several countries have experienced some success with the completion of CCS demonstration projects (a full list can be found in Annex 1), which could provide valuable lessons learned for Qatar and the GCC region as a whole on the development and deployment of CCS technology. These include:

- **United States:** The United States has 23 large-scale CCS projects in operation or in various stages of development—the greatest number of any country or region. It has also been a leader in CCS-related research, development and demonstration (RD&D). One of the most well-known large-scale CCS projects in the U.S. is the Kemper County integrated gasification combined cycle (IGCC) project, due to come online in 2014, which will capture 3.5 million tons per annum of CO_2 (around 65 percent of the plant's annual CO_2 emissions). Another major project is the Texas Clean Energy Project, a 400 megawatt electrical (MWe) IGCC coal-based power plant that will capture 2 million to 3 million tons per annum of CO_2 and is expected to be in operation by 2015.[124]

- China: As the world's largest producer and consumer of coal, China is taking a systematic approach to deploying CCS, based on the establishment of a strong R&D base and followed by the roll-out of large-scale demonstration projects. CCS has also been supported under China's science and technology programs during the 10th and 11th five-year planning periods, and support for the technology has increased under the current 12th Five-Year Plan. China has set the goal of developing carbon capture experimental projects in the thermal power, coal-chemical, cement and steel sectors and developing fully integrated carbon capture, utilization and storage (CCUS) demonstration projects, with the captured CO_2 to be used for enhanced oil recovery and geological storage. China currently has 12 CCS pilot projects at different stages of development.[125]

- Norway: Norway is the biggest per capita producer of oil and natural gas outside of the Middle East. As part of its commitment to a carbon-neutral economy, Norway has made CCS one of the "three pillars" of its energy policy, announcing that all new gas-fired power plants will be required to implement CCS. Norway is home to four large-scale CCS projects, including the full-scale CO_2 Capture Mongstad (CCM) plant, projected to be one of the world's largest, with full-scale CO_2 collection potentially beginning in 2020.[126]

- Australia: Australia is rich in petroleum, natural gas and coal reserves and is a significant net energy exporter. The country is highly supportive of CCS and has a number of initiatives designed to accelerate the development and demonstration of CCS technologies. Australia also houses the Global CCS Institute. A number of CCS projects (commercial, demonstration and R&D) are underway in Australia, the largest being the Gorgon Project in Western Australia, which is expected to store between 3.4 million and 4.1 million tons of CO_2 each year.[127]

As governments develop strategies for developing and commercializing CCS, international cooperation can strengthen project commitments, increase confidence in the technology, help establish carbon capture as common practice, and promote knowledge and technology transfer. Countries are also cooperating to develop CCS. For example, among the GCC countries, Qatar, Saudi Arabia and Kuwait are jointly funding CCS research.[128]

Additional examples of international cooperation include the EU-China Partnership on Climate Change, which helps develop near-zero emissions coal (NZEC) plants in China using CCS technology; joint funding between the U.S. and Canada for the Weyburn-Midale CO_2 Monitoring and Storage Project that will establish best practices for sequestration in spent oil wells (total project funding is around $5.2 million); and an agreement between the U.S. and China to develop a research group on CCS technology as part of the U.S.-China Clean Energy Research Center (CERC).[129]

Qatar's Domestic CCS Initiatives

Over the last few years Qatar has begun to explore CCS on a project basis:

- In September 2012, a $70 million, 10-year research partnership between Shell, Qatar Petroleum, Imperial College London and the Qatar Science & Technology Park established the Qatar Carbonates and Carbon Storage Research Centre (QCCSRC). The center will help build Qatar's capacity in CCS and cleaner fossil fuels and will involve over 40 academic staff, postdoctoral researchers and Ph.D. students.

- In October 2012, Qatar University's Gas Processing Centre (GPC) announced the release of a Carbon Capture and Management Road Map, which outlines key milestones in the CCS technology roadmap for Qatar.[130]

- In March 2012, the Qatar Fuel Additives Company (QAFAC) ordered a large-scale CO_2 recovery plant from Mitsubishi Heavy Industries with plans for installation within its methanol production plant by autumn 2014.

In addition, Qatar has provided a basic regulatory framework to enable work in this area. In Qatar, law 30 of 200: environmental protection sets the general basis for all Qatari environmental protection legislation. One of the law's aims is to "counteract the effects of pollution in its various forms, and prevent damage as well as instant and long-term environmental effects of construction, industrial, agricultural and economical activities." Qatari efforts to mitigate greenhouse gas emissions with technologies such as CCS fall under the auspices of this piece of legislation.

RECOMMENDATIONS

Qatar's current efforts on the development of CCS technology are fragmented and initiatives to date have been project-oriented. A concerted effort to develop expertise on CCS could make Qatar a leader in the region and contribute to domestic climate change goals.

Policy Framework: A National CCS Program for Qatar

A national CCS program could include the following elements:

- Mapping CCS storage sites in Qatar. GPC has taken important steps in this direction but gaps remain.

- Developing a legal and regulatory framework for CCS development. Qatar already has a regulatory framework for the capture and storage for EOR. The most significant gap here regards long-term storage and questions of liability in the event of leakage. Measures to tackle this issue could include conducting a thorough environmental assessment of CCS storage sites; demonstrating suitable technologies for CO_2 containment; undertaking risk assessments for industrial applications; and establishing industry best practices and guidelines for storage and monitoring.

- Generating a report on CCS projects globally, associated costs, and the challenges of CCS to help inform decisions in Qatar on the best way forward on CCS and identify best practices that are specific to Qatar and the GCC region.

Build Expertise

One issue for Qatar to consider is whether it wants to develop an industrial-scale CCS demonstration plant. This could be done as part of EOR or GTL activities. Other issues to consider include cost and regional collaboration.

In addition to developing CCS capacity, Qatar should also seek to develop specific CCS technologies. Such technologies should build on Qatar's domestic experience with gas extraction and using CO_2 for EOR with an eye to the commercialization of these technologies for use in other countries.

Gaining expertise and lessons learned from international experience should also be a priority, and in this spirit Qatar should take a proactive approach in international forums such as the UNFCCC's discussions on CCS in the CDM, and other multilateral forums such as the Carbon Sequestration Leadership Forum and Global CCS Institute, to ensure global policies on CCS are developed in ways that achieve the goals of developing CCS globally and that are consistent with and support Qatar's CCS efforts. This approach can include developing bilateral and regional partnerships to share experience. For instance, Qatar should consider membership in the Global CCS Institute, which could help provide support for and facilitate the deployment of commercial-scale CCS projects.

Financing for CCS

Support for CCS will also need to address the costs not only for development in Qatar but also for economic viability on the global level. As noted, making CCS commercially viable is needed to enable the ongoing consumption of fossil fuels in a carbon constrained world. In this regard, a price on carbon will be key.[131] In this case, Qatar should also consider how it can support efforts to price carbon regionally and globally. This could include consideration of a role for carbon pricing in Qatar and the GCC as means for improving the economic viability of CCS.

Setting a price on carbon could be done in cooperation with other countries and regions with experience pricing carbon such as the EU. For example, the EU is working with China through a €25 million ($34 million) financing agreement to provide expertise and assistance in setting up pilot emissions trading systems in several Chinese cities.[132] China's seven pilot emissions trading schemes will cover one-fifth of the country's energy use and will be running by 2015.[133] A nationwide scheme is being designed for deployment by 2020 and is expected to have a CO_2 price starting at $10 per ton in 2020 rising to $30 per ton in 2030.[134]

A carbon price will increase the relative price of carbon intensive energy such as fossil fuels and present challenges for Qatar and the GCC. Since Qatar is the world's largest natural gas exporter, pricing carbon should make clear the climate change benefits of gas and hasten a transition away from coal, providing economic benefits for Qatar. That said, a carbon price will lead to increased oil prices though the impact on demand is likely to be minimal, as carbon prices, at least in the early years, are likely to be low, and demand for oil is highly inelastic.[135]

Additionally, even without an explicit carbon price, there is already a shadow carbon price as a result of some countries' domestic climate change policies. The U.S. EPA regulation that would increase the cost of producing CO_2 emissions is one example.[136] As a result, the choice is better understood as whether an explicit carbon price will produce better outcomes for Qatar, the GCC and the globe. In this regard, an economy-wide carbon price is the most efficient way of reducing GHG emissions because, by equating the marginal cost of abatement with the carbon price, emissions costs are equalized across the economy.[137] Additionally, a carbon price is an effective and efficient way of incentivizing the development of clean energy technologies such as CCS and energy efficiency (discussed in more detail in the energy efficiency chapter).