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Carbon Capture, Utilization and Storage and Enhanced Hydrocarbon Recovery - Policies and Trends in the ESCWA Region

Imad Sleiman

El Habib El Andaloussi

UN-ESCWA

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1- Acronyms

2DS	2^oC increase scenario
6DS	6^oC increase scenario
AFED	Arab Forum for Environment and Development
BP	British Petroleum
CAMRE	Council of Arab Ministers Responsible for the Environment
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilization and Storage
CDM	Clean Development Mechanism
COP	Conference of the Parties
DoE	United States Department of Energy
EE	Energy efficiency
EHR	Enhanced Hydrocarbon Recovery
EOR	Enhanced Oil Recovery
ESCWA	United Nations Economic and Social Commission for Western Asia
GCC	Gulf Cooperation Council
GHG	Greenhouse Gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LAS	League of Arab States
OAPEC	Organization of the Arab Petroleum Exporting Countries
OPEC	Organization of the Petroleum Exporting Countries
RE	Renewable energy
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

I- Introduction

The League of Arab States (LAS) / Council of Arab Ministers Responsible for the Environment (CAMRE) in its 19th session (2007) has adopted the Arab Ministerial Declaration on Climate Change. The participating ministers and heads of delegations called on the 13th Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) to "develop and transfer clean technology, including technologies for the production of clean fuel, capturing and storing carbon dioxide (CCS); and to adopt CCS within the framework of the Clean Development Mechanism (CDM) projects".

The Arab countries are sitting on 43% of the proven world oil reserves and 40% of the proven natural gas reserves, and their oil and gas productions are respectively 32% and 20% of the global oil and gas output [BP, 2012]. Sixteen out of twenty-two Arab countries are oil and gas producers. Out of these sixteen countries ten are exporters of oil and/or natural gas of which four are among the 10 biggest global producers (three of them belong to the Gulf Cooperation Council (GCC) countries)

ESCWA[1] member countries and particularly hydrocarbon producing countries such as the GCC countries are exhibiting increased interest in carbon capture, utilization and storage (CCUS) which is considered a promising technology for both climate change mitigation and enhanced oil and gas production. The public sector in most of these countries has taken the lead and invested in CCUS technology principally toward establishing in-house expertise in the field and facilitating technology transfer. Several local academic institutions introduced CCUS programmes, CCUS research and development facilities were established, and a number of pilot projects integrating CCUS technology either in existing industries or in new industries were initiated with captured CO2 used for enhanced hydrocarbon recovery (EHR) or as raw material in chemical processes.

[1] ESCWA comprises 17Arab countries in Western Asia and North Africa: Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, The Sudan, The Syrian Arab Republic, Tunisia, The United Arab Emirates and Yemen.

The present paper overviews the current commitment of the GCC countries toward integrating CCUS within their portfolio of tools to reduce atmospheric CO_2 emissions and preparing for the eventual maturity of their oil fields by extending their productive life using CCUS.

II- Carbon capture, utilization and storage

A) Climate change and CCS

The latest Intergovernmental Panel on Climate Change (IPCC) report [IPCC, 2013] released recently validates the conclusions reached in earlier reports on climate change and the uncertainty that accompanies such change on the delicate balance of the earth's ecological system. The increased concentration of carbon dioxide and other greenhouse gases (GHG) in the atmosphere is affecting the energy balance of our planet by locking more energy from the sun within the earth boundaries causing it to warm up beyond its natural periodical oscillation. Actions to mitigate climate change are pressingly needed to curtail the risk of irreversible destabilization of our climate system. As the measures undertaken globally do not commensurate with the level of threats we are facing as mankind multilateral cooperation to reduce the atmospheric GHG emissions should be pursued more vigorously.

It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century (IPCC, 2013).

Experts have identified a portfolio of technical tools and instruments which are effective in curbing the growing trend in CO_2 emissions if implemented in concert (Figure 1). End-use fuel and electricity efficiency has the most potential in lowering GHG emissions (42% cumulatively by 2050) followed by renewables (21% cumulatively by 2050). However, the implementation rate of renewable energy, energy efficiency and energy conservation measures will most probably remain below the level of

world energy demand increase for the foreseeable future; fossil fuel shares in the global energy mix will continue to grow. CCS has the capacity to enhance the sustainability of the energy system and is projected to achieve 14% cumulative reduction of CO_2 emissions by 2050.

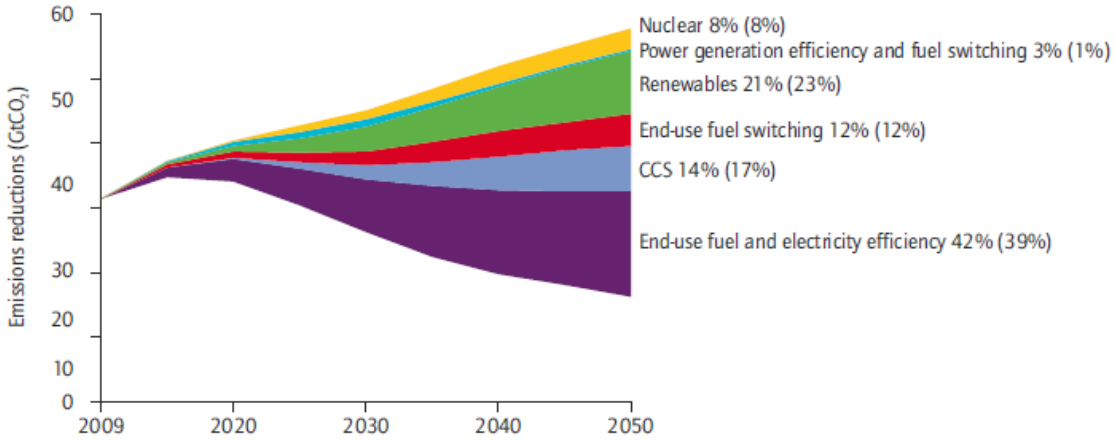

Figure 1: CCS contributes 14% of total emission reductions through 2050 in 2°C increase scenario (2DS) compared to 6° C increase scenario (6DS) [IEA, 2013]. Note: numbers in brackets are shares in 2050. For example, 14% is the share of CCS in cumulative emission reductions through 2050, and 17% is the share of CCS in emission reductions in 2050, compared with the 6DS

B) <u>CCS and enhanced oil recovery</u>

CCS was originally developed and used in the USA in the 70s for enhanced oil recovery (EOR) in mature oil fields [DOE], [DOE, 2010]. At the end of viability of the secondary oil extraction phase (water flooding) oil miscible CO_2 is compressed and injected in the oil wells (miscible flooding) to facilitate the displacement of otherwise unrecoverable oil and boost production. Naturally sourced CO_2 were used in EOR such as from natural gas processing plants (that would have otherwise been vented) or from natural underground CO_2 sources. While the oil and gas industry invested early on in the research and development on CCS technologies to increase their profits, the idea of ridding the atmosphere of carbon emission by capturing it at the source and storing it underground gained acceptance within environmental groups.

III- The Gulf Cooperation Council

The GCC is a political and economic union of six Arab countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. The GCC countries are endowed with vast hydrocarbon reserves estimated at 33% and 21% of proven world reserves of conventional oil and natural gas respectively [OPEC, 2013], [OAPEC, 2011]. They have been enjoying vast revenues from the oil and gas exports which saw their prices rise, triggered by a surge in global energy demand lead by the emerging countries, mainly China and India. According to the Organization of Petroleum Exporting Countries (OPEC) the total world demands of crude oil in 2012 averaged 88.8 million barrels per day while total supply averaged 89.8 million barrels per day [ESCWA, 2013]. The share of crude oil exchanged by the GCC averaged 16.9 million barrels per day in 2012 which generated revenues equal to 637 billion US dollars [ESCWA, 2013].

Table 1: Proven oil reserves and production in the Arab economies (end 2011) [AFED, 2013]. [a] Conventional and unconventional oil.

	Proven reserves (m b)	Share of world reserves[a] (%)	R/P ratio	Production (1000 b/d)	Share in world production (%)	Ratio export to consumption
GCC countries	**495.0**	**29.9**	**69.5**	**19,505.0**	**23.3**	**5.8**
Bahrain	0.1	<0.05	7.0	47.0	0.1	5.0
Kuwait	101.5	6.1	97.0	2,682.0	3.2	7.7
Oman	5.5	0.3	16.9	889.0	1.1	6.7
Qatar	24.7	1.5	39.3	1,638.0	2.0	6.0
Saudi Arabia	265.4	16.1	65.2	11,153.0	13.3	3.8
United Arab Emirates	97.8	5.9	80.7	3,096.0	3.7	5.3
Other major oil producers	**202.4**	**12.2**	**110.5**	**5,020.0**	**6.0**	**4.2**
Algeria	12.2	0.7	19.3	1,884.0	2.3	4.2
Iraq	143.1	8.7	>100	2,635.0	3.2	3.0
Libya	47.1	2.9	>100	502.0	0.6	5.5
Total Arab world	**713.6**	**43.2**	**74.4**	**26,262.0**	**31.4**	**3.3**
World	**1,652.6**	**100.0**	**54.2**	**83,576.0**	**100.0**	**n/a**

However, since August 2012, OPEC member countries have seen lower demand for their crude oil while production in the United States and Canada has increased noticeably following the development

of unconventional oil such as shale oil, tight oil and tar sand extraction. Added to continued economic slowdown in the industrialized world the price of crude oil declined and is projected to fall further.

A) Climate change position of the GCC

The position of the GCC countries on climate change was slow to evolve from skepticism in the 1990 to becoming concerned and active in the international arena helping in the negotiations and calling for more multilateral efforts to reduce GHG atmospheric emissions [Hertog, 2009]. Most notable of such recent involvement is the hosting of the UNFCCC COP18/CMP8 in Doha, Qatar, in 2012, and bringing to Abu Dhabi the permanent quarters of the International Renewable Energy Agency (IRENA). Five GCC member countries signed and ratified the Kyoto Protocol in 2005 with Bahrain signing it in 2006 [UNFCCC]. They have embarked on showcase projects in renewable solar energy, while looking for ways to promote energy efficiency without upsetting economic and social development, and are pursuing research and setting pilot projects on CCS. They are trying to build a reputation of leadership in sustainable energy by investing heavily in renewable energy models.

B) Challenges facing the energy sector in the GCC countries

1- Desert climate: The GCC countries are characterized by a hot climate, fresh water scarcity (average yearly rainfall from 59 mm in Saudi Arabia to 125 mm in Oman [World Bank]) and arid land. However, relying on abundant local energy resources, cities have rapidly expanded in large part due to the availability of artificial indoor climate control and sea water desalination; local rural to urban migration has increased significantly driven by better job opportunities and services. Expatriates are no more wary of the harsh environment characterizing this part of the world, and they are attracted to these countries mostly for financial incentives bringing skills and expertise and playing an important role in the economic expansion.

2- Demographic changes: The populations of the GCC countries have increased at an average rate of 3.12% between 2000 and 2009 from 29.9 million to 38.4 million [ESCWA, 2009]. In

addition to straining resources the added population increases the pressure on the governments to expand their economies and create enough job opportunities to place the bulging youth population.

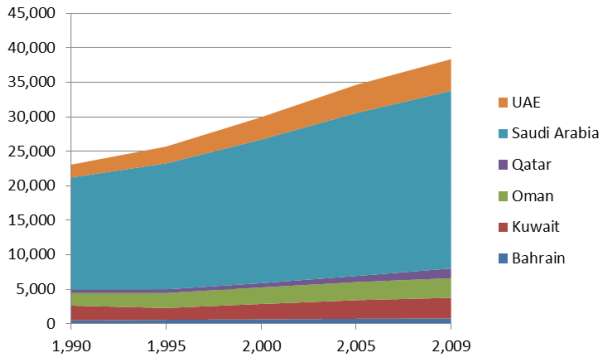

Figure 2: Population estimates of the GCC countries (nationals & non-nationals) [ESCWA, 2009].

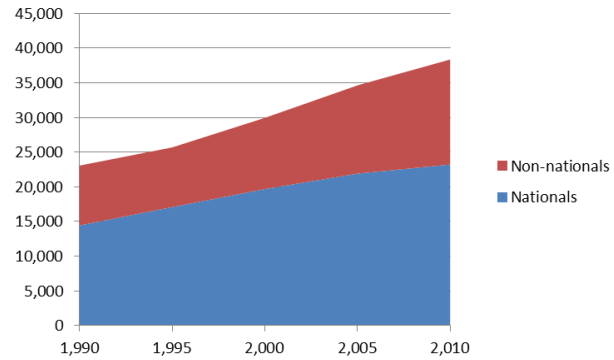

Figure 3: Non-nationals (2010) residing in the GCC countries are equal to 65% of the national population (2009) [ESCWA, 2009].

However, the need for expatriates has become more critical as the economies are diversifying and more skills are required to sustain the economical expansion. The expatriate population in the GCC countries has expanded from 10.3 million in 2000 to 15.1 million in 2010 [ESCWA, 2009].

3- Hydrocarbon revenue dependency: The total GDP (nominal) of the GCC countries equaled 1 084 billion US dollars in 2010. During the same year the hydrocarbon export revenues were estimated at 480 billion US dollars, making up almost 44% of GDP and 80% of government revenues (Table 2) [AFED, 2013]. Such dependency subjects the national economies to the effect of the global hydrocarbon market uncertainties. In addition the oil and gas resources are unsustainable and the proven existence of large reserves only delays the imminent requirement to have other sources of revenue.

Table 2: The oil and gas sector's contribution to GDP (nominal) and government revenues in the GCC countries' economies (2010) [AFED, 2013].

	GDP (US$ million)	Hydrocarbon Sector (US$ million)	Share of Hydrocarbon Sector (%)	Share of Hydrocarbon Revenues in total Government Revenues (%)
GCC countries	**1,084,391**	**479,547**	**44.2**	**80.7**
Bahrain	22,945	5,591	24.4	81.8
Kuwait	124,244	64,009	51.5	93.8
Oman	63,199	30,118	47.7	81.7
Qatar	128,593	71,642	55.7	60.8
Saudi Arabia	447,762	214,145	47.8	90.4
United Arab Emirates	297,648	94,042	31.6	75.9

To this respect the GCC countries have set targets to reduce their dependency on hydrocarbon exports through transformation of their economy away from oil and gas. They embarked on an expansion strategy during the last decade opting for economic diversification [Devaux, 2013].

4- Increased internal energy consumption and CO_2 emissions: The high economic expansion is fuelled by higher internal consumption of oil and gas mainly in the electricity sector. This is attributed to (i) the growing national population and increasing expatriate population which taxes heavily the electricity sector and industrial sea water desalination sector; (ii) the industrial sector, including oil and gas industries such as petroleum refining and petrochemicals, and industries that use oil and gas as energy input such as cement, iron and steel etc.; and (iii) low priced energy offered to consumers in the local market [Hertog, 2009]. What exacerbates the situation is the high energy intensity that still permeates most sectors, partly due to the lower efficiency of heat engines operating in high temperature environment characterizing the GCC countries.

As a consequence to the above the atmospheric CO_2 emissions in the GCC countries have increased in parallel with the increase in fossil fuel consumption. The rate of emission increase has outpaced the world average increase by almost 5 times (Figure 4, table 3).

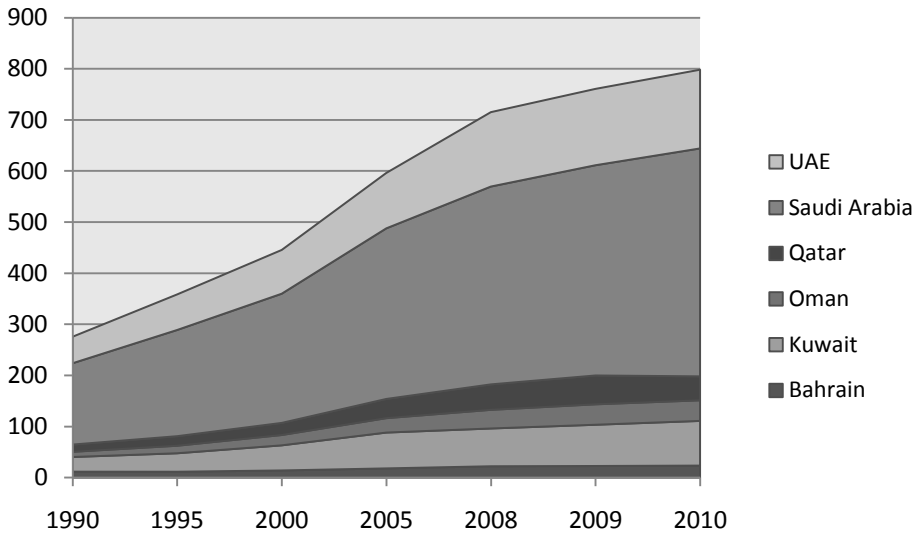

Figure 4: Atmospheric CO_2 emissions in the GCC countries (million tons of CO_2) [IEA, 2012]

The energy subsidy policy prevalent in the GCC countries and other Arab countries started when the price of oil was low and reserve to production ratio high. However as the energy price drove up and consumption increased the lost revenue was becoming significant and consumption was increasing at a very high rate drawing large investments to the electricity sector to keep up with demand. End users as well as the industry had no incentives to apply energy efficiency actions and reduce their consumption in electricity and save on water which is produced in energy intensive desalination plants.

Table 3: CO_2 emissions in the GCC countries (2010), & pPercentage increase in atmospheric CO2 emissions in the GCC countries between 1990 and 2010 [IEA, 2012]

	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	UAE	GCC countries	World
CO2 emissions, (million tons of CO2, 2010)	24	87	40	47	446	154	798.2	30,276
% change 1990-2010	102	204	293	362	180	197	190	44

C) Opportunities for energy sector in the GCC countries

1- Setting up technological parks:

Since 2003 the GCC countries have benefited from the global high demand on energy which resulted in unprecedented price hike. The revenues from the export of oil and gas produced large surpluses in the treasuries of these countries. Becoming more perceptive to the climate change issues and with the atmospheric carbon emissions growing rapidly in parallel with their expanding economies the rulers in these countries wanted to project an image of responsibility towards the challenges facing societies globally. They increased their involvement with international organizations concerned with the climate change mitigation and adaptation. Since these countries did not have the infrastructure for scientific and technological research and development, it would have taken at least another generation to develop the threshold requirement for a sustainable knowledge society. They opted to create technological islands with mission to advance the knowledge and technologies in several fields related to the fight against climate change, specifically in the energy field (Hertog, 2009). Decisions in several GCC countries were made to build technological parks allocating generous funding to finance state of the art constructions and facilities and to procure the latest scientific equipment; they attracted high caliber scientists and technologists, and partnered with renowned academic institutions with objective to establish graduate level educational facilities to attract the brightest local and international students who will contribute to the sustainability of these technological structures through continuing research and development.

2- Potentials for renewable energy and energy efficiency:

The ESCWA region has made stride in adopting renewable energy (RE) and energy efficiency (EE) policies and implementing RE and EE projects. In RE projects solar and wind energy are the main focus to the region. The UAE is the leader in the region with 22.5 MW of installed capacity.

In 2013 UAE inaugurated the world's largest CSP plant, Shams 1. Saudi Arabia and UAE have developed policy frameworks to stimulate local manufacturing and innovation [AFED, 2013].

3- Conditions appropriate for CCS:

The Middle East region has the highest potential for incremental oil production from CO2-EOR, with estimates ranging between 80 and 120 billion barrels to 2030 [IEA, 2008]. CCS is a useful tool to enhance hydrocarbon recovery and increase revenues from oil and gas. Oil companies and governments in the hydrocarbon producing countries have vested interest to invest in the R&D of CCS technology in all its components. The difference of CCS for EOR and CCS for climate change is restricted to the objective sought. Both processes use the same technology. The difference lies in the quantity of carbon to be stored in the oil fields, with EOR focusing on increasing oil production with minimal CO_2 use while CCS for climate change puts emphasis on storing the maximal quantity of CO_2 in parallel to boosting oil production.

There are many factors that favor CCS in the GCC region. The fact that all power generation plants are fossil fuel based implies that significant proportions of carbon emissions are concentrated in large point sources. In addition heavy industries in the region are concentrated in a number of locations making them suitable for CCS integration in terms of carbon capture and optimal in transport infrastructure framework design. CO_2 storage sites in the region are widely available. The depleted oil and gas fields in the region are primary storage sites and are naturally proven for their containment characteristics. They offer large reservoirs which can be used for storing many decades of carbon production in the region. These sites should be inspected of course to make sure that the oil and gas extraction process did not compromise their integrity by causing serious fractures in their walls that may result in carbon leakage.

All six GCC countries are oil producers though with varied level of production. EOR is used to boost the production of oil wells that have had their first (natural) and second (water flooding) stage extractions expired. During a third extractive stage an oil miscible gas is injected into the

wells to reduce the viscosity of oil thus making its extraction more manageable. In natural gas producing countries gas is reinjected into the oil wells for EOR. However as natural gas has become a valuable commodity, the use of CO_2 in EOR will free the gas used for EOR thus generating additional revenues.

Table 4: Gross production of natural gas and gas reinjected (2011) [Lecarpentier, 2012]

	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	UAE	GCC countries	World
Gross production	15.48	13.75	32.77	160.17	102.43	92.79	417.39	4127.59
Gas reinjected	2.86	0	2.96	5.9	0.03	23.97	35.72	449.49

IV- Hurdles to potential wide CCS deployment: considerations to new policy framing in the GCC countries

It is important to point out that the GCC countries will not adhere to any policy on climate change that might affect their economic development and growth [Liu, 2012].

As mentioned before CCS is receiving a lot of interest from different stakeholders in the GCC countries. CCS is still at the exploratory stage. Several GCC governments are committing funds for research and development on CCS (principally on carbon capture and geological storage) and approving deployment of carbon capture technology integration either for retrofitting operational industrial plants or in new plants. However CCS on its own has no market value considering the current carbon valuation does not justify the investments needed. While EOR will utilize CCS to boost oil production and release injected natural gas, deploying CCS on a large scale requires policy actions to help it overcome the market barriers. The implication is injection of public funds until CCS sustainability is achieved or as long as the financing is justified through positively imparting other sectors and balancing benefit vs. cost. However there will always be factors that are outside the control of the policy makers that have repercussions on the implementation of policies, most important of which is the unpredictability of the world commodity market which determines whether oil and gas prices are favorable to CCS financing [Little].

There are still hurdles that need to be dealt with to facilitate wide deployment of the technology in the region, many of them stemming from global considerations.

- Lack of binding strategies and legal framework on carbon management – low carbon value and therefore low incentive for carbon trade [Benyahia, 2012],
- Very few commercial deployment of CCS around the world to permit building experience and knowledge on,
- No clear policy regarding a CCS roadmap for the region,
- Working toward including CCS for EOR under the Clean Development Mechanism of the Kyoto Protocol (CDM)
- Large upfront investment and increased operating cost for integrating CCS in power plants and industrial plants. With current price support on energy by the GCC governments this will mount the energy bill that these countries have to cover; this challenge must be dealt with in parallel with the potential CCS deployment
- Weak or non-existent legal and regulatory framework specifically regarding responsibilities for stored carbon during the pre- and post-closure of storage sites and cross-border shared sites; monitoring, reporting and verification mechanisms should be clarified and established,
- More R&D is needed on the capture technology and on understanding the dynamics of CO_2 storage and movement in geological formations, particularly regarding risks to fresh water aquifers,
- Health risks from CO_2 plumes should be evaluated
- Technology transfer mechanisms
- Capacity building to prepare for potential CCS deployment in the region
- Capture technology which constitutes the highest cost in CCS deployment favors capture of CO_2 from high emitting energy systems such as coal power plant, whereas carbon emissions from oil and gas are at a much lower concentration which entails higher cost capture per unit CO_2 [Benyahia, 2012].

V- CCS activities in the GCC countries

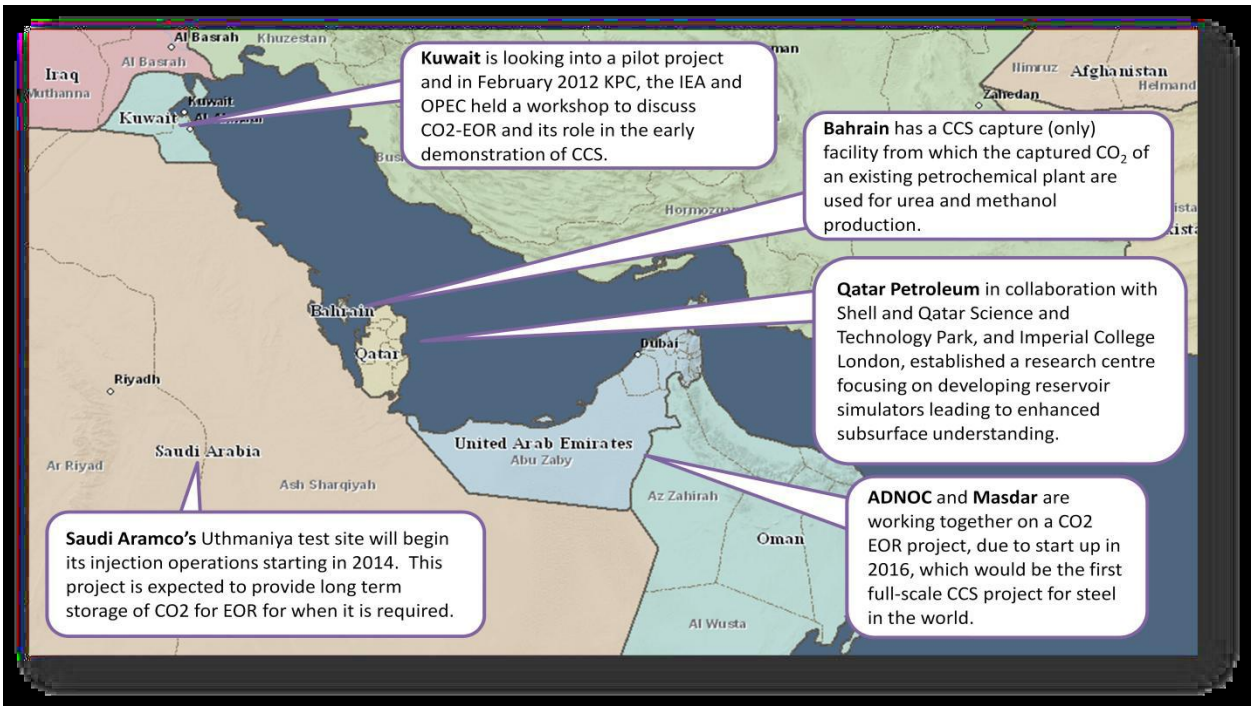

Figure 5: Current and planned project on CCUS in the GCC countries [GCC, 2013]

A) Saudi Arabia

Current CCS activities in Saudi Arabia are primarily focused on basic technical and policy research [Liu, 2012]. Some of the institutions engaged in CCS research are:

- King Abdulaziz City for Science and Technology (KACST) – basic technical research on CCS. Technology Innovation Center for CCS (KACST-TIC CCS) research has been focusing on oxy-fuel combustion, mobile capture, site assessment, and measurement, monitoring and verification (MMV) of CO_2 storage.
- King Fahd University of Petroleum & Minerals (KFUPM) – basic technical research on CCS.
- King Abdullah University of Science and Technology (KAUST) – basic technical research on CCS.
- King Abdullah Petroleum Studies and Research Center (KAPSARC) - Research focused on CCS technologies, economics and policies.

- Saudi Aramco – Developed a comprehensive research framework on CCS, including CO_2 capture (mobile capture, oxy-fuel combustion, and chemical looping combustion), storage, and EOR technologies. It is working on the first CO_2-EOR demonstration project in Saudi Arabia. The main objective of the project is to assess the applicability to sequester CO_2 in a mature zone within an oil reservoir. The design of the CO_2-EOR is based on a reservoir simulation study and has a comprehensive monitoring and surveillance plan. CO_2 will be ready for injection by 2013.
- Saudi Aramco is currently constructing its first CCS test site in Uthmaniya, which will begin injection operations starting in 2014. The project is expected to meet Saudi Arabia's objective to provide long-term storage of CO2 for EOR, although gas liberation is not a driver [GCC, 2013]. Linde has been awarded a contract to build the world's largest CO2 purification and liquefaction plant for Jubail United Petrochemical Company (UNITED), a manufacturing affiliate of SABIC (Saudi Basic Industries Corporation). The plant will be located in Jubail Industrial City, Saudi Arabia. The plant is the first carbon capture and utilization (CCU) project of this size to be realized in Saudi Arabia. The reduction of CO2 emissions is an important aim in both SABIC's and Linde's sustainability strategy. The facility will be designed to compress and purify around 1,500 tonnes per day of raw carbon dioxide coming from two nearby ethylene glycol plants. The purified gaseous CO2 will be pipelined through the piping corridor of the Royal Commission of Jubail to three SABIC-affiliated companies for enhanced methanol and urea production. Methanol is a basic commodity for the chemical industry and urea is used for fertilizer production. In summary, an estimated 500,000 tonnes of CO2 emissions will be saved each year. The plant will also be capable of producing 200 tonnes per day of liquid CO2 with food grade quality which will be stored and thereafter supplied by truck to the beverage and food industry. Linde Engineering Dresden will be responsible for the concept and basic engineering, front end engineering design (FEED) and detailed engineering, procurement and construction (EPC) of the facility to be completed on a fast-track schedule. Mechanical completion is set to be achieved in 2015 [Hassan, 2013].

- In 2011 Saudi Aramco announced plans to start by 2013 injecting carbon dioxide to boost production at its Ghawar oil field, the world's largest. Aramco will pump 1.1 million cubic meter CO2 a day from Hawiyah and Uthmaniyah gas processing plants into a section of the field. Ghawar produces about 5 million barrels of crude a day on average and the deposits have reserves of 88 billion barrels. Aramco has planned and designed the CO2 capture facility and transport system.

B) Qatar [Global CCS Institute]

- In September 2012, a $70 million, 10-year research partnership between Shell, Qatar Petroleum, Imperial College London and the Qatar Science and Technology Park, recently established the Qatar Carbonates and Carbon Storage Research Centre (QCCSRC). The center will help build Qatar's capacity in CCS and cleaner fossil fuels, involving over 40 academic staff, postdoctoral researchers and PhD students.
- In October 2012, Qatar University's Gas Processing Centre (GPC) announced the release of a Carbon Capture and Management Road Map.
- In March, 2012, the Qatar Fuel Additives Company (QAFAC), a major producer in Qatar, placed an order for a large-scale CO2 recovery plant from Mitsubishi Heavy Industries (MHI). The QFAC plans to install this plant within its methanol production plant, near Doha, by autumn 2014.

C) UAE (Global CCS Institute)

- Considering such factors as the investment environment, technological capacity and a commitment to clean energy, a recent survey supported by the Global CCS Institute identified the UAE as the most suitable amongst countries in the Middle East and North Africa (MENA) for CCS development
- CCS is explicitly acknowledged by the UAE Government as a key component of national greenhouse gas (GHG) mitigation plans in its national communications to the UNFCCC, as well as its submissions to the International Energy Agency for the Clean Energy Ministerial.

- Masdar, Abu Dhabi's state-owned clean energy company, which is responsible for multi-billion dollar clean energy and education programs, has initiated work on CCS following endorsement by the Executive Council, the Abu Dhabi legislative body. Masdar, in partnership with the Abu Dhabi Executive Affairs Authority (the Secretariat of the Executive Council), is currently developing a legal and regulatory regime for CCS.
- The Dubai Integrated Energy Strategy 2030 also calls for consideration of CCS-equipped coal power in the next ten years, and the emirate of Ras Al Khaimah has announced feasibility studies for a CCS-equipped coal plant. No coal plants are envisaged without CCS.
- The UAE continues to develop, through Masdar, a CCS network linking CO2 emitters to users, namely for enhanced oil recovery (EOR).
- ESI CCS project, United Arab Emirates (EOR & CCS); operation date 2015 [ESI],
- Emirates Aluminum CCS Project, United Arab Emirates (EOR & CCS); operation date 2018 [Emirates Aluminun]

D) <u>Bahrain</u>

- Bahrain has a CCS capture (only) facility from which the captured CO_2 of an existing petrochemichal plant are used for urea and methanol production [GCC,2013].

E) <u>Kuwait</u>

- Kuwait is still exploring the potential for CCUS and EOR.

VI- Conclusion

As non-Annex I Parties to the Convention the GCC countries have no binding commitments to reduce their atmospheric CO2 emissions since the Kyoto Protocol places a heavier burden on developed nations under the principle of "common but differentiated responsibilities". However the carbon emissions generated by the GCC countries have increased rapidly during the past decade. While the ratio of their population to the world population is 0.55%, their CO2 emission contributions to the global emissions are 2.63% (2010) [IEA, 2012].

The GCC countries have made appreciable efforts in preparing to climate change mitigation. They have actively promoted technology transfer and established energy research centers with emphasis on renewable energy, energy efficiency and CCUS. Several related projects were implemented or initiated some of them in partnership with the private sector (oil companies mainly).

The GCC countries have interest in implementing CCUS for EOR, recovering oil and releasing reinjected natural gas. CCS projects in the GCC countries are not confined to power plants but encompass industrial plants. CO_2 utilization extends beyond oil recovery and will be used as raw material in chemical synthesis processes.

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