

Energy Sector: Mitigation Options of Climate Change

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CO₂ emissions related to fuel combustion in the Arab region increased by 247 percent from 1990 to 2010, significantly outpacing population growth over the same period (+55.77 percent). Over 95 percent of these emissions were related to the use of oil and gas.

As non-annex I countries, Arab states are not required to meet any specific emission reduction or limitation targets in terms of commitments under the UNFCCC, or the Kyoto protocol. However, mitigation measures are already in progress.

Accelerated developments are taking place for introducing renewables; fuel switching in industry and transport; use of combined heat and power; reduction of generation, transmission and distribution losses; domestic and industrial efficiency programs to enable establishment of an economic structure that prioritizes energy efficiency.

The key for Arab countries to mitigation options of climate change is to lay a sound foundation for further evolution to low carbon energy systems. Pathways to achieve high CO₂ mitigation levels comprise the following:

- Widespread diffusion of zero- and low-carbon energy supply technologies, with substantial reductions in energy intensity.
- Comprehensive mitigation efforts covering all major emitters.
- Technology and Financial transfers from industrialized countries to support decarbonization.

According to UNEP most of the developing countries can produce the same volume of commodities by about 40 percent less primary energy. Thus the potential for cutting off primary energy consumption through Energy Efficiency (EE) in the Arab Countries is huge. Renewable Energy also has a high potential of reducing future GHG emissions of the Arab Countries. Those are indigenous resources which have the potential to provide energy services with zero or almost zero emissions of both greenhouse gases and air pollutants. In the long term, the region could potentially shift from exporting fossil fuel to exporting clean energy.

The technological revolution under way in power generation, where advanced systems are replacing steam turbine technologies, does support the long-term goal of near-zero air pollutant and greenhouse gas emissions without complicated end-of-pipe control technologies. Continued use of fossil fuels in a carbon-constrained world requires that carbon capture and storage (CCS) becomes a major carbon mitigation activity.

The widespread interest in nuclear power reflects a broadly shared perception of the need to shift away from fossil fuels because of concerns about climate change. In some countries, such as Egypt, nuclear power also is seen as a way to reduce the dependence on depleted oil and gas or on imported fuels.

Also, within the context of the global carbon market, CDM projects in the Arab countries need to increase in number and scale.

Most importantly, the private sector will lead in developing and deploying most of the effective approaches, but will need a stable governance framework. However, reaching almost zero or even negative GHG emissions will require the Arab countries to embark on rapid introduction of policies and measures to integrate climate change into local and national priorities.

I. INTRODUCTION

Fossil fuels are the predominant primary energy at present in the Arab world, accounting for nearly 98.6 percent of commercial energy use. They are also the dominant fuel for power generation: producing about 93 percent of the Arab World's electricity today (Abdel Gelil et al. 2011) and projected to provide a similar fraction in 2030 under a business-as-usual (BAU) scenario (IEA, 2008c). Today, fossil fuels are the most mature and economic source for power generation. However, they also account for most local pollution and global carbon dioxide emissions. The future of fossil power generation in a carbon-constrained world depends on a compromise between growth in electricity demand and reduction in carbon dioxide emissions (Larson et al. 2012).

Electricity demand has invariably increased along with economic growth in the Arab countries. In 2010, Arab world primary commercial energy supply was 580.3 million tons of oil equivalent (Mtoe), including oil, natural gas, hydropower, and new renewables. Oil and natural gas supplies ranked first with a fraction of 98 percent (IEA, 2012a). Table 1 gives the evolution of total primary energy supply in the Arab countries and the total CO₂ emissions from fossil fuel combustion during the period 1971-2010 (IEA, 2012b).



Although electricity demand has increased all over the world, including the Arab countries, the Gulf Cooperation Council (GCC) countries' demand for electricity has increased at thrice the global average over the last few years; there are different reasons for this anomalous behavior, the main ones being the higher-than-average economic growth rate (reflected in the significant increase of the GCC countries' GDPs), and the policy of encouraging huge development projects in the domestic, service and infrastructure sectors, especially the UAE and KSA (Qader, 2009).

The International Energy Agency (IEA) identified 3 of the GCC countries as those with the highest per capita energy consumption in the world, and furthermore concluded that the six GCC countries contribute approximately to 50 percent of the cumulative Arab countries' CO₂ emissions (IEA, 2012a&b). KSA leads the six GCC countries, followed by UAE, Kuwait, Qatar, Oman, and Bahrain, with a total contribution of 721.2 MtCO₂ in 2010. Egypt is ranked the second Arab country with a contribution of 177.6 MtCO₂ in 2010, following the KSA (446 MtCO₂). The United Arab Emirates (UAE) is the world's third largest emitter of greenhouse gas (GHG) per capita. Rapid rise in CO₂ emissions is related to economic and social development, and the need for energy supply to the continuing development. The same rapid growth in fossil-based electricity generation is recorded in conjunction to the above rapid rise in CO₂ emissions in these countries (see Table 1).

This high dependency of the Arab region on fossil fuel resources raises critical questions, which demand clear answers: Where are we now, and where are we headed? Is a cost-effective climate change mitigation strategy possible?

This chapter highlights the policies needed to implement a cost-effective mitigation strategy in the Arab region as well as technologies and measures that are most appropriate to reducing GHG emissions.

II. MAJOR EMITTERS OF CARBON DIOXIDE IN THE ARAB REGION

Carbon dioxide emissions related to fuel combustion in the Arab region increased by 247 percent from 1990 to 2010, reaching 1,363 Mt, significantly outpacing population growth over the same period

TABLE 1

EVOLUTION OF TOTAL PRIMARY ENERGY SUPPLY (TPES) IN THE ARAB COUNTRIES AND TOTAL CO₂ EMISSIONS FROM FUEL COMBUSTION DURING: 1971-2010 (IN MILLION TONNES OF OIL EQUIVALENT-MTOE, AND MILLION TONNES OF CO₂-MTCO₂, RESPECTIVELY)

Region		1971	1980	1985	1990	1995	2000	2005	2008	2009	2010
Algeria	TPES	3.5	11.2	17.7	22.2	24.1	27.0	32.4	37.4	40.7	40.4
	TCO ₂ *	8.9	28.4	43.2	52.7	56.8	63.5	79.6	89.7	99.1	98.6
Egypt	TPES	7.8	15.2	25.7	32.3	35.3	40.7	62.7	71.9	71.4	73.3
	TCO ₂	20.3	41.9	64.8	78.4	83.1	101.3	152.6	175.3	172.7	177.6
Libya	TPES	1.6	6.9	10.0	11.3	15.8	16.6	17.6	19.2	21.9	19.1
	TCO ₂	3.7	18.6	22.5	27.4	35.1	39.7	42.5	47.0	49.8	51.6
Morocco	TPES	2.4	4.9	5.6	6.9	8.6	10.2	13.1	15.0	15.1	16.5
	TCO ₂	6.8	14.0	16.5	19.6	26.0	29.4	40.1	43.5	42.7	46.0
Sudan	TPES	7.0	8.4	9.5	10.6	12.0	13.3	15.1	15.1	15.9	16.2
	TCO ₂	3.3	3.7	4.2	5.5	4.6	5.5	9.2	12.4	13.5	13.7
Tunisia	TPES	1.7	3.3	4.2	4.9	5.8	7.3	8.3	9.4	9.0	9.6
	TCO ₂	3.7	7.8	9.6	12.1	14.2	18.0	20.2	21.5	21.3	21.9
Bahrain	TPES	1.4	2.8	4.2	4.4	4.9	5.9	7.5	9.2	9.5	9.8
	TCO ₂	3.0	7.4	10.4	11.7	11.6	14.1	18.1	22.3	22.8	23.6
Iraq	TPES	4.1	9.6	13.8	19.7	34.5	25.9	26.9	28.5	32.5	37.8
	TCO ₂	10.4	27.0	36.8	53.4	97.5	70.3	74.9	73.4	91.9	104.5
Jordan	TPES	0.5	1.5	2.6	3.3	4.3	4.9	6.7	7.1	7.5	7.2
	TCO ₂	1.3	4.3	7.4	9.2	12.2	14.4	18.0	18.5	19.3	18.6
Kuwait	TPES	6.1	10.5	14.0	9.1	14.9	18.8	26.4	27.9	30.2	33.4
	TCO ₂	14.0	26.6	37.1	28.7	36.1	49.1	70.1	73.9	80.7	87.4
Lebanon	TPES	1.8	2.5	2.3	2.0	4.4	4.9	5.0	5.4	6.6	6.5
	TCO ₂	4.5	6.6	6.5	5.5	12.8	14.1	14.5	15.8	19.1	18.6
Oman	TPES	0.2	1.1	2.1	4.2	6.1	8.1	10.8	15.9	14.9	20.0
	TCO ₂	0.3	2.2	5.7	10.2	14.7	20.2	28.2	36.5	40.0	40.3
Qatar	TPES	0.9	3.3	5.4	6.2	7.9	10.4	16.9	21.5	23.5	30.2
	TCO ₂	2.2	7.7	12.1	14.1	18.7	23.7	37.6	49.8	56.4	66.1
KSA	TPES	7.4	31.1	46.0	59.8	87.5	101.3	145.5	154.1	157.9	169.3
	TCO ₂	12.7	99.1	122.6	159.1	207.8	252.8	333.8	387.1	411.4	446.0
Syria	TPES	2.4	4.5	7.8	10.5	12.1	15.8	20.8	23.1	21.2	21.7
	TCO ₂	6.0	13.1	21.1	28.2	32.8	39.8	54.9	62.7	57.2	57.8
UAE	TPES	1.0	7.2	13.7	20.4	27.7	33.9	43.2	58.3	60.4	62.1
	TCO ₂	2.4	19.1	35.6	51.9	69.6	85.6	108.4	145.6	149.4	154.0
Yemen	TPES	0.7	1.3	1.7	2.5	3.4	4.7	6.6	7.1	7.4	7.2
	TCO ₂	1.2	3.4	4.8	6.4	9.3	13.2	18.8	21.1	21.6	21.7

* Total CO₂ emissions from fuel combustion in the Arab countries, sectoral approach.
Source: IEA: CO₂ Emissions from Fuel Combustion – Highlights, 2012.

TABLE 2

CO₂ EQUIVALENT (CO₂E) EMISSIONS FROM FOSSIL FUEL COMBUSTION IN SOME ARAB COUNTRIES, AS PER THEIR NATIONAL COMMUNICATIONS

Arab Country	National Communication Report	Year of Inventory Calculation	Emissions from Fossil Fuel Combustion (Mt CO ₂ e)	Percentage of Total Emissions (%)
Egypt	Second NC, 2010	2000	116.30	60.2
Morocco	Second NC, 2010	2000	32.29	50.9
Sudan	First NC, 2003	1995	16.70	18.7
Tunisia	Initial NC, 2001	1994	15.25	65.3
Bahrain	Second NC, 2012	2000	17.25	77.1
Jordan	Second NC, 2009	2000	14.91	74.0
Lebanon	Second NC, 2011	2000	13.85	74.86
KSA	Second NC, 2010	2000	237.55	92.10
Syria	Initial NC, 2010	2005	58.35	74.00
UAE	Second NC, 2010	2000	116.11	89.60

Source: UNFCCC: Arab National Communication Reports, 2012.

(+55.77 percent) (IEA, 2012b). Over 95 percent of these emissions were related to the use of oil and gas, with oil-based transport and gas-based power generation having the largest growth over the last two decades.

Methane (CH₄) is the second largest GHG contributing to anthropogenic global warming. Energy-related sources in the Arab region include, oil production (from associated natural gas), and natural gas production, transport, and distribution (leaks) (Emberson et al., 2012).

Today, many Arab countries have produced their First and Second National Communications to the United Nations Framework Convention on Climate Change (UNFCCC) using the Global Warming Potential (GWP) and emission factors of the Intergovernmental Panel on Climate Change (IPCC). Carbon dioxide equivalent anthropogenic emissions from fossil fuel combustion were calculated at the values and percentages given in Table 2 (UNFCCC, 2013).

In all Arab countries, the energy usage is the main source of GHG emissions because they are all principally dependent on fossil fuels. Minor shares come from agriculture, industrial processes, land-use change, and agriculture and waste sectors. Table 3 gives the total CO₂ emissions from fossil fuel combustion of the Arab region by sector in 2010.

- **Energy-related activities** are responsible for a major share of anthropogenic emissions of GHGs, other radiative forcing substances, and air pollutants into the atmosphere (see Table 2). Electricity-related GHG emissions, mainly from fossil fuel combustion account for approximately 30-35 percent of total fuel combustion emissions, including carbon dioxide (CO₂), methane (CH₄) and some traces of nitrous oxide (N₂O) (IPCC, 2007d) (Emberson et al., 2012) (see Table-3).
- **The industry sector** in the Arab Countries represents 25 – 50 percent of their GDP. Although the Maghreb Arab Countries do not have high industrial intensity, industrial pollution is dominant. Fast industrial development in the Mashreq Arab Countries has considerably increased the consumption of energy and other raw materials. Some Arab Countries have witnessed fast growth in oil production and refining. This has been accompanied by the establishment of several industries based on oil production. The result has been a significant increase in industrial pollution and GHGs accounting for around 30-33 percent of total fuel combustion emissions (IEA, 2012b).
- **Transport** is comparatively the smallest energy service category when assessed in terms of useful energy. But due to low conversion effi-

TABLE 3
**SECTORAL CO₂ EMISSIONS FROM FOSSIL FUEL COMBUSTION OF THE ARAB COUNTRIES IN 2010,
 IN MILLION TONNES OF CO₂**

Region	Total CO ₂ emissions from fuel combustion	Electricity and heat production	Other energy industry own use	Manufacturing industries and construction	Transport	of which: road	Other sectors	of which: residential
Algeria	98.6	25.0	11.1	12.7	33.3	29.7	16.4	13.1
Egypt	177.6	66.0	14.8	33.4	38.4	35.4	24.9	15.2
Libya	51.6	28.0	3.1	6.3	12.1	12.1	2.2	2.2
Morocco	46.0	16.0	0.8	7.6	10.6	10.6	11.0	4.2
Sudan	13.7	2.7	0.5	2.3	6.8	6.7	1.4	0.8
Tunisia	21.9	7.4	0.1	5.1	6.0	6.0	3.3	1.6
Bahrain	23.6	8.5	4.5	6.8	3.6	3.6	0.2	0.2
Iraq	104.5	50.3	4.0	8.2	29.7	29.7	12.2	12.2
Jordan	18.6	8.4	0.6	2.3	5.2	5.1	2.2	1.3
Kuwait	87.4	48.0	12.2	15.0	11.7	11.7	0.5	0.5
Lebanon	18.6	11.1	-	1.3	5.0	5.0	1.2	1.2
Oman	40.3	15.7	7.9	8.5	6.3	6.3	1.9	0.5
Qatar	64.9	13.9	20.3	21.2	9.2	9.2	0.3	0.3
KSA	446.0	176.9	74.4	86.3	104.4	102.3	4.0	4.0
Syria	57.8	27.6	1.5	8.8	12.2	12.0	7.7	4.4
UAE	154.0	58.4	2.1	67.2	25.7	25.7	0.6	0.6
Yemen	21.7	5.1	3.3	0.9	6.2	6.2	6.2	1.9

Source: IEA: CO₂ Emissions from Fuel Combustion – Highlights, 2012.

ciencies, it stands for some 28 percent in total primary energy. Road transportation (cars, two and three-wheelers, buses and trucks) are the dominant technologies for providing mobility of people and goods (Grubler et al., 2012). The transport-related GHG emissions in the Arab countries account for approximately 20-26 percent of total energy-related emissions in Egypt, Libya, Morocco, Syria, KSA & Lebanon, and for approximately 27-33 percent in Yemen, Jordan, Tunisia, Iraq and Algeria. It becomes lower to 14-17 percent in Kuwait, Qatar, Oman, Bahrain and UEA, but it goes higher in Sudan to approximately 50 percent (IEA, 2012b).

III. TECHNOLOGIES AND MEASURES TO REDUCE GHG EMISSIONS

A. Current Policies and Measures

As non-annex I countries, Arab states are not required to meet any specific emission reduction or

limitation targets in terms of commitments under the UNFCCC, or the Kyoto protocol. However, mitigation measures are already in progress.

Various policies and measures related to internalizing reduction of GHG emissions, as advocated in the UNFCCC, have been developed in many Arab countries.

Accelerated developments are taking place for introducing renewables; fuel switching in industry and transport; use of combined heat and power to produce electricity and water; reduction of generation, transmission and distribution losses; domestic and industrial efficiency programs and energy-efficient buildings to enable establishment of an economic structure that prioritizes energy efficiency.

Examples of the current mitigation policies and measures in the Arab countries, summarized in Table-4, are based on those described in national communication reports as well as national plans and country studies documents.

TABLE 4

EXAMPLES OF POLICIES AND MEASURES IMPLEMENTED AND PLANS ANNOUNCED FOR MITIGATION OPTIONS IN THE ARAB COUNTRIES

Algeria	<ul style="list-style-type: none"> • Reducing of gas flaring by 50%. • Building of four gas-CSP plants with total capacity 1700 MW; of which 250 MW solar (will be gradually commissioned through 2015). • Introduction of medium-big scale RE power generation: CSP: 500 MW in 2010 and Wind: 100 MW; Solar PV: 5.1 MW; Solar Thermal: 170MW; Cogeneration: 450 MW by 2015.
Egypt	<ul style="list-style-type: none"> • Expand access to renewable energy resources to reach a contribution of 20% of the total electrical energy demand by 2020, of which 7200MW wind farms. Today, 547 MW wind farms are operating along the Suez Gulf, 140MW ISGCC is operating at Kureimat and two 100MW each of CSP are announced in Comombo, in addition to two PV 20MW each. • Switching to using natural gas in substitution to oil for power generation. • Enhancing electricity and gas grid-interconnection across borders of neighboring states. • Reinforcing energy efficiency standards, expanding energy efficiency labeling for household appliances, application of energy efficiency code for buildings and disseminating efficient lighting. • Transport sector improvements using natural gas in commercial vehicles; extending the electrified underground transportation to new areas in Greater Cairo; electrification of Cairo- Alexandria Line by 2020; electrification of Cairo - Upper Egypt Line around 2030; intensifying the use of environmentally sound river transport; facilitating the replacement of old taxis; and vehicles utilizing fuel cells are to grow as their economics improve. • Launching a program to build a number of nuclear power generating plants, initiating the necessary steps to have the first 1000MW plant operational by 2017.
Jordan	<ul style="list-style-type: none"> • A series of BOO-based wind farms at Aqaba, Kamsha, Al-Hareer, Ibrahimya, Fujaij, Ma'an with a total installed capacity of 600-1000 MW by 2020. • Promoting utilization of solar water heaters (SWH) in 50% of household in Jordan by 2020 (the 2008 numbers were about 14%). • Solar PV 300-600 MW by 2020. • Energy saving projects in industrial sector cover ceramic, food and canning, paper, steel, plastic, chemical and mining industries.

Source: UNFCCC: Arab National Communication Reports, http://unfccc.int/nationa_reports/non-annex_i_nal-com/items/2979.php, 2012.

B. Medium- and Long-Term Options

There are multiple means for lowering GHG emissions from the energy system while still providing energy services (Pacala and Socolow, 2004). Energy services are the tasks to be performed using energy. In order to assess the potential contribution of a single mitigation mean, competing mitigation options therefore must be considered as well (IPCC, 2007d).

i. Energy Efficiency

According to UNEP report on Energy Conservation in Developing Countries, (UNEP, ERS-16-16-85), most of the developing countries can produce the same volume of commodities by about 40 percent less primary energy. Thus the potential for cutting off primary energy consumption through Energy Efficiency (EE) in the Arab Countries is huge.

Energy efficiency in the many sectors of the economy is where the Arab region has relatively lagged behind, due to the difficulty of articulating and enforcing the complex and detailed policies required for improving efficiency, in addition to the complexity and higher level of administrative capacity required for pursuing this objective (ESMAP, 2009).

However, several aspects of policy for energy efficiency have been recently proposed and assessed for the Arab countries by the Regional Center for Renewable Energy and Energy Efficiency (RCREEE, 2010).

The assessment indicated that very few countries relatively achieved some progress in every aspect as presented in Table 5.

Tunisia appears to be the only country that has performed well in this regards, with some plausible results to show. Otherwise, countries have taken

- Introduction of a total 1500 MW oil shale-based power plants during: 2012-2014.
- Introduction of a total 1200 MW nuclear power into the national power system during 2020-2030.
- 2.3% per year penetration rate for solar thermal applications in commercial and residential sectors.

Saudi Arabia

- Several initiatives to implement energy conservation and to reduce peak load demand.
- National Energy Efficiency Program (NEEP).
- Thermal Energy Storage (TES) initiative.
- Establishing the Center of Research Excellence in RE at KFUPM in 2007.
- Hybrid system initiative (wind-diesel).
- Solar electricity: 41,000 MW by 2032 (25,000 MW CSP and 16,000 MW PV)⁽¹⁾
- Many research programs conducted by Saudi Aramco to implement carbon management (CM), including CO₂-EOR.
- Saudi Aramco operates the world's largest single gas collection system.
- North-South Railway (NSR) project.
- 20 km long the Al-Mashaer Al-Mugaddassah metro line (in operation since 2010).
- A lot of R&D projects in the areas of solar energy, clean fuel production, emission reduction and water resources.

United Arab Emirates

- Renewable energy: commitment to deploy renewable energy sources (i.e., solar PV and wind) equal to 7% of the total on-grid power generation capacity by 2020.
- Solar CSP 100 MW Shams-1 plant in Abu Dhabi.
- Introduction of a single next-generation pressurized water reactor (1,400 MW), followed by three nuclear plants, each of capacity 1400 MW to displace equivalent baseload electricity from natural gas-fired units.
- Abu Dhabi Vision 2030 calls for shifts from private modes of transport to public modes and scales this initiative up to the UAE level.
- Use of compressed natural gas (CNG) in bus fleets.
- The Abu Dhabi MASDAR Initiative is investing heavily in the research, development and integration of technologies that will sharply reduce CO₂ emissions of fossil fuel-fired power generation linked with a carbon capture and sequestration (CCS) network.

scarce steps, but tangible results are almost absent. The only measures observed outside of Tunisia are in Algeria, with respect to the establishment of an energy efficiency law and the dissemination of information; and Egypt, with respect to the establishment of a strategy and targets (Patwardhan et al., 2012).

Over the long term, dramatic gains in efficiency are possible for all the Arab countries at all stages of energy conversion, particularly from useful energy to energy services. Analysis shows that current technologies are not close to reaching theoretical limits, and that improvements of an order of magnitude for the whole energy system may eventually be achieved.

There are basically 2 measures to manage energy demand in the Arab countries: (1) mandate that something should be done or (2) make use of the market and the economic instruments (Table 6). Mandating is typically used to give

explicit information or explicit tasks about certain technologies and actors that should be activated, whereas the market acceptance is used when the object cannot be easily identified, but the performance characteristic can be well defined (Lisa Ryan et al., 2011). The task is to keep the energy system working and to shift from carbon-fat to carbon-lean systems.

Industry is the area where the easiest energy efficiency progress may be achieved, because of the large scale of emissions and the concentration in hands of few actors, whose behavior can more easily be influenced and monitored (Luciani, 2012).

In the industrial sector, energy efficiency measures can be broadly split into the following categories:

- widespread adoption of best available technology for new investments;
- retrofit of existing plants to improve energy efficiency;
- optimization of energy and material flows

TABLE 5 POLICY SCAN OF ENERGY EFFICIENCY IN THE ARAB REGION

	Strategy and Targets	Energy Efficiency Legislation	Pricing Policy	Energy Efficiency Agencies	Labeling and Standards	Financial Incentives	Energy Efficiency Obligations	Audits and Promotion of ESCOs ^(*)	Transport and Spatial Planning	Dissemination of Information
Algeria		•			•	•	•			•
Egypt	•				•		•	•	•	
Morocco	•			•						•
Sudan										
Tunisia	•	•		•	•	•	•	•	•	•
Bahrain								•		•
Jordan			•	•	•	•				
Kuwait					•					
Lebanon				•				•		•
KSA					•					
Syria				•				•		
Palestine		•	•							
UAE									•	•

* ESCOs: Energy Service Companies.

Source: RCREEE (2010). "Policies for Efficiency and Renewable Energy in RCREEE Group of Countries"; Cairo, Egypt.

through systems design, quality improvements, lifecycle product design, and enhanced recycling; and

- switch to renewable energy.

The adoption of best available technology and systemic approaches to optimizing the use of energy for industrial processes can yield an efficiency improvement of around 30 percent (IEA, 2007; Price and McKane, 2009; Saygin et al., 2010). Moreover, a switch to 25 percent renewable energy throughout the manufacturing industry yields a 10 percent "efficiency" gain through electrification and reduced used of fossil resources.

Power generation, also, is a key area for energy efficiency. As for Saudi Arabia and the UAE, lower energy efficiency is probably due to the fact that several gas plants are used for meeting seasonal peak demand: these are open-cycle gas turbines rather than combined-cycle (Luciani, 2012).

The synergy between power generation and water desalination is a major theme for efficient use of

energy in the Arab region. The optimization of the interface between power generation and water desalination is extremely important and carefully looked at in the region.

The reliance on open cycle gas turbines for power generation and the importance of water desalination are, at the same time, important features that may allow for more efficient deployment of renewable energy sources, such as wind and solar, whose main drawback is intermittency (Luciani, 2012).

With respect to water desalination, the key to achieving higher efficiency is in greater reliance on technologies such as reverse osmosis, which absorb electricity. As water can be stored in large quantities, while electricity cannot, it would be possible to operate the desalination plants at times of low electricity demand and store the water. At times when electricity demand is near its peak, water desalination could be stopped or slowed down, and water demand would be satisfied drawing from the water reservoirs.

Another aspect that has been flagged for attention in the context of energy efficiency is the high level of transmission losses (ESMAP, 2009). The integration of grids across borders is expected to lead to an improvement of transmission efficiency.

The residential sector is also where a relatively larger proportion of energy is used in the Arab countries. The share of the residential sector in total electricity consumption exceeds 50 percent in Kuwait, Saudi Arabia, Bahrain and Oman, and reaches about 40 percent in Egypt. Improving efficiency of electricity consumption in the residential sector has therefore special importance as an instrument to address the excessive growth in electricity demand.

The most important opportunities for energy savings in the residential and commercial sector in the Arab region are to be found in improving the quality of buildings, minimizing the demand for lighting and air conditioning. It would require a major shift in economic strategy to change direction and pursue a substantial improvement of energy efficiency in buildings. Nevertheless, some initiatives signal increased awareness of the problem: the Abu Dhabi Municipality, for instance, has recently launched a major energy efficiency study of the city's buildings' stock⁽²⁾ (Luciani, 2012).

In the absence of a major improvement in the quality of buildings, it is still possible to pursue greater efficiency in the equipment and technologies that are used for household services. Some countries, such as Egypt and Saudi Arabia, have introduced labeling of appliances for energy consumption, including air conditioning equipment and Frigidaire's, and Abu Dhabi will soon do the same.

The potential for the utilization of alternative technologies is also significant. Solar air conditioning based on adsorption, air conditioning from gas and district cooling are all technologies that have considerable promise.

ii. Renewable Energy

Renewable energy sources (including biomass, solar and wind) that use indigenous resources have the potential to provide energy services with zero or almost zero emissions of both greenhouse gases and air pollutants (Turkenburg et al., 2012).

The Arab region enjoys tremendous renewable energy resources. Saudi Arabia and North Africa have vast stretches of desert areas with abundant sunlight, which can be exploited for the production of solar power. It is quite obvious that CSP is highly

TABLE 6

APPROACHES, TYPES OF MEASURES, SUITABILITY AND EXAMPLES OF DEMAND-SIDE MANAGEMENT TO IMPROVE ENERGY EFFICIENCY

Approach	Type	Example of Measure	Suitability for Industry	
Mandated	Standards	1. Minimum performance (MEPS)	Small motors, Lighting	
		2. Top-runner standard	c.f. Energy Star computers	
	"Agreed Actions"	3. Voluntary Agreements	For branches	
		4. (Technology) Procurements	LCC Procurement guidelines	
	Delegated Actions	By actor	5. Regional bodies	Chambers of commerce
			6. Municipalities	-
		By Means	7. Commitments	For SMEs
			8. Certificates	Quota obligations
Market Acceptance	Price-responsive customers	9. Taxes; Tax reduction	Combined with audits and agreements	
		10. Price elasticity (Demand Response)	Common and neutral for all types	
	Non-price responsive Customers	"Commoditizing" energy efficiency	11. Energy Services (ESCO) and Performance Contracting (EPC)	Outsourcing and facility management
			12. Labels	-

Source: Schock et al. (2012). "Energy Supply Systems" in GEA; Cambridge University Press, Cambridge, UK.

EFFICIENT LIGHTING SYSTEMS IN THE ARAB REGION

Ibrahim Abdel Gelil

Energy-efficient lighting technologies are economical, commercially viable and technologically available, but due to several barriers, they have not reached their market penetration potential. A growing number of countries in the Arab region have already taken actions to transit to more efficient lighting systems. Replacing incandescent lamps in the residential sector is one of the most obvious and easiest methods to achieve energy-efficiency in the region. The transition to efficient lighting can occur at a very low cost with existing technology and provide immediate results. The UNEP/GEF en.lighten initiative, developed estimates for 130 countries with the objective of calculating the potential electricity savings, CO₂ emission reductions and the economic benefits that could be realized from phasing out inefficient lighting and replacing them with compact fluorescent lamps (CFLs). Out of the 130 countries analyzed, 18 were from the Arab region. Eliminating inefficient lighting in the region would save nearly 37.8 Twh of electricity and slash 24.8 Mt of CO₂. Lighting consumes nearly 34 percent of the total Arab's electricity consumption. Potential energy savings and CO₂ emission reduction varies between different

countries based on their pattern of energy demand, fuel mix of electricity generation, and energy efficiency. Lighting represents the highest percentage of electricity consumption in Algeria (41.3 %) and Sudan (35.5%), while Saudi Arabia and Egypt are the largest consumers of electricity and thus have the highest saving potential.

Some Arab countries have already begun initiatives to transition to efficient lighting. These national programs are in various stages of development. To support the transition, countries have formulated different policies and measures and, in most cases the preferred approach has been the implementation of fiscal incentives to reduce the initial cost of the CFLs. Five countries (Egypt, Lebanon, Morocco, Tunisia, and UAE) have already distributed around 30 million CFLs in total. Additionally, some countries like Egypt, Tunisia, and Lebanon have announced that they will ban the sale of all incandescent bulbs by specific target years. Bulk distribution of CFLs is a positive first step forward to develop market for efficient lighting. It highlights the benefits of CFLs such as economic viability, reliability, and efficiency. It also serves to educate the public on the availability of this technology, overcome the barrier of initial high cost of CFLs, increase the demand for CFLs

promising RE technology for power generation in the entire Arab region (see Box on NOOR 1).

Solar photovoltaics, CSP and grid-connected wind installed capacities are growing in many Gulf and North Africa countries. However, renewables share in the Arab electricity production is still humble. Currently, renewable energy sources, including hydro-electricity, supply 1.3 percent of the total Arab region's primary energy demand (Abdel Gelil et al., 2011). For instance, hydro-electricity and new renewables (wind and solar) have contributed 8.2 percent and 1.27 percent, respectively in the total Egypt's electricity generation in 2012 (EEHC, 2012). Even so, it will likely be decades before these new renewables add up to a major fraction of total energy consumption, because they currently represent such a small percentage (GEA, 2012).

As indicated in Table 6 of chapter 3 on Renewable Energy, many Arab countries have already set renewable energy targets to scale up penetration of renewable energy into their national energy mix, some countries have developed national renewable

energy strategies, and many countries have adopted a set of policy instruments, such as feed-in-tariff, to foster development of renewable energy resources.

Thus, next to energy efficiency, RE has a high potential of reducing future GHG emissions of the Arab Countries.

Arab countries have the option to invest now in the huge potential of solar and wind power, and should strive to take a leading position in developing and deploying renewable energy technologies in the region and aspire to become major exporters of green energy. (Check chapter 3 of this report for details on renewable energy options to mitigate climate change)

iii. Advanced energy technologies

a. Fossil Energy Technologies

Today, fossil fuels are the most mature and economic source for power generation. Present and future perspective show that a radical transformation of the

to encourage suppliers to enter the market, as well as helping to achieve quick and impactful load reduction of the power systems. However, bulk distribution programs are not sufficient to secure sustainable transformation to efficient lighting. These programs should be implemented within a broader and integrated policy framework. Key elements of this integrated approach include: the development of Minimum Energy Performance Standards (MEPS), supporting policies to help restrict supply of inefficient lighting and promote demand of MEPS-compliant products; Monitoring Verification and Enforcement (MVE) mechanisms; and, environmentally sound waste management of CFLs at the end of their life.

Studies reveal significant similarities with regard to policies implemented for the switch to efficient lighting in the region. In almost all the countries examined, they have formulated a comprehensive policy package that; contains energy price reform, strengthens the legislative and institutional framework, provide fiscal incentives, develops standards and labeling schemes, and raises public awareness. Furthermore, almost all of countries in the region have been conducting public awareness campaigns to promote energy efficiency and efficient

lighting, even if they don't currently have any programs in place for switching to CFLs. In these cases, the effectiveness of such campaigns in changing consumer opinion and buying habits needs to be measured.

While many countries in the region, such as Morocco, Jordan, Egypt, and Tunisia have already established integrated energy-efficiency strategies, targets or legislation into their national energy policy frameworks, these steps are yet to be taken in other countries like the Gulf States (GCC). Here, heavy energy price subsidies and the abundance of fossil fuels have hindered investment in energy efficiency including efficient lighting.

Reference

Abdel Gelil, I., Draft Regional Report on Efficient lighting in the Middle East and North Africa, accessed on 24 May 2013 at http://www.enlighten-initiative.org/portal/Portals/26107/documents/ConferenceMaterial/MiddleEast_NorthAfrica/Regional%20Report%20MENA%20Final.pdf

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fossil energy landscape is feasible for simultaneously meeting the multiple sustainability goals of wider access to modern energy carriers, reduced air pollution health risks, enhanced energy security, and major greenhouse gas (GHG) emissions reductions.

Fossil fuels will dominate energy use in the Arab region for decades to come. Two facts apply to developing and industrialized countries alike. First, fossil fuels must be used judiciously— by designing energy systems for which the quality of energy supply is well matched to the quality of energy service required, and by exploiting other opportunities for realizing high efficiencies. Second, continued use of fossil fuels in a carbon-constrained world requires that carbon capture and storage (CCS) becomes a major carbon mitigation activity (Larson, E., et al., 2012).

The technological revolution under way in power generation, where advanced systems are replacing steam turbine technologies, does support the long-term goal of near-zero air pollutant and greenhouse gas emissions without complicated end-of-pipe





control technologies. Natural-gas-fired combined cycles (NGCCs) that offer low costs, high efficiency, and low environmental impacts are being chosen wherever natural gas is readily available. Cogeneration is more cost-effective and can play a much larger role in the energy economy-if based on gas turbines and combined cycles rather than on steam turbines.

Reciprocating engines and emerging microturbine and fuel cell technologies are also strong candidates for cogeneration at smaller scales, including commercial and apartment buildings. Imported coal gasification by partial oxidation with oxygen to produce syngas (mainly carbon monoxide and hydrogen) makes it possible to provide electricity through integrated gasifier combined cycle (IGCC) plants with air pollutant emissions nearly as low as for natural gas combined cycles (Larson, E. et al., 2012). Imported coal might be considered a viable alternative for some Arab counties, like Egypt. Coal is unevenly distributed and abundant, and can be converted to liquids, gases, heat, and electricity, although more intense use demands viable CCS technologies if greenhouse-gas emissions are to be limited. (Lepinski et al., 2009).

Methane is a diverse and flexible fuel which, when combusted, provides both heat and/or electricity. It can also be used in the transport sector in the form of CNG, LNG, or compressed or liquefied biomethane.

Fossil fuels other than petroleum can be converted in the Arab region to transportation fuels. Technologies are available and commercially operated today for converting natural gas, coal, or biomass into liquids that closely resemble diesel and gasoline derived from crude oil. Also, there is renewed interest in higher alcohols for both gasoline and diesel blending (GEA, 2012). Furthermore, there is now growing interest in the production of synthetic gasoline from synthesis gas via a methanol intermediate. This is so called methanol-to-gasoline process.

One approach to reducing GHG emissions below petroleum-fuel levels is to exploit negative GHG emissions opportunities to offset the emissions. One important opportunity is synthetic fuels production from biomass with CCS.

In addition, hydrogen is not used as a transportation fuel today, but it is appealing as it allows the

QATAR PETROLEUM: AL-SHAHEEN CLEAN DEVELOPMENT MECHANISM (CDM) PROJECT

Al-Shaheen, implemented by Qatar Petroleum, is a model of a Clean Development Mechanism (CDM) project in the oil sector. The project activity is the recovery and utilization of associated gas produced as a byproduct of oil recovery activities at the Al-Shaheen oil field, which is operated by Maersk Qatar Oil, under agreement with Qatar Petroleum. Prior to 2004, associated gas at the Al-Shaheen oil field was primarily flared, with the remaining gas utilized for onsite consumption (about 3 percent).

The project activities cover recovery and transmission of the associated gas, and ultimately utilization at the gas processing plant.

Captured associated gas is injected into a gas pipeline for transport to Mesaieed gas processing plant. The gas products include dry gas, LPG and condensate, which are utilized for the electricity in the national grid and for local industry consumption. This contributes to Qatar's energy efficiency efforts by increasing the power supply without raising fossil fuel consumption.

Qatar's accession to the Kyoto Protocol on 11 January, 2005, as a non-Annex I nation, made it eligible to the CDM benefits. Subsequently, Qatar Petroleum initiated the formal procedure to register the Al-Shaheen project activity under the CDM. The project, which followed the full cycle of CDM process, was used by Qatar Petroleum as a model for other CDM projects in the Qatari energy and industry sectors.

The project falls under the category of "Fugitive Emissions" from fuels (solid, oil and gas) according to the UNFCCC classification. The approved methodology of "recovery and utilization of gas from oil wells that would otherwise be flared" was applied to this project. The Project Design Document (PDD) was prepared meeting the requirement of base line and monitoring methodology, including economic attractiveness and barriers. The PDD was validated in late 2006, and Al-Shaheen was registered as a CDM project with UNFCCC in May 2007.

The overall responsibility for the monitoring of the project is the Health, Safety and Environment (HSE) Regulation and Enforcement Directorate of Qatar



Petroleum. The first Monitoring Report was submitted to UNFCCC in May 2009.

The Project has undergone a comprehensive verification process leading to the issuance of a Certified Emission Reductions (CERs) certificate. The total quantity of Certified Emission Reduction (CER) units issued by UNFCCC's CDM Executive Board to this project are being carried out for selling the CERs generated from the Al-Shaheen in the market.

The success of the Al-Shaheen CDM project is considered a major milestone for the energy and industry sector in Qatar. According to Dr. Mohammed Al-Sada, Minister of Energy and Industry and Chairman & Managing Director of Qatar Petroleum, "At Al-Shaheen, we have comprehensively demonstrated the use of the CDM and technologies to reduce greenhouse gases. I am very positive that its success will encourage more such projects not only in Qatar, but the entire Middle East."

*Based on material provided by Qatar Petroleum (QP).
QP is corporate AFED member.*

SOLAR DESALINATION IN AL-KHAFJI, SAUDI ARABIA

Hussam Khonkar

King Abdulaziz City for Science and Technology (KACST) is currently building what will be the world's largest solar-powered desalination plant, in the city of Al-Khafji on the shores of the Gulf in Saudi Arabia, next to the border with Kuwait. Work on this green project has been underway since 2011 in response to the King Abdullah Initiative for Solar Water Desalination, which aims at meeting all new desalination requirements of the kingdom from renewable energy.

Saudi Arabia has a paramount challenge in the next 20 years, as it will see its electricity demand almost triple. A key driver for the rise in demand for local oil is the increase in demand for fresh water, which requires building desalination plants. Saudi Arabia has the world's largest installations of water desalination plants, representing more than 18 percent of global production. Approximately, 1.5 million barrels of oil are daily used locally to produce electricity and desalinated water across the Kingdom. Of that total, about 11 percent is used to meet the demand for domestic and industrial water use; while water used for irrigation comes mainly from underground aquifers. Saving oil for export is a vital issue for Saudi Arabia.

Recognizing the challenges, Saudi Arabia has established King Abdullah City for Atomic and Renewable Energy (KA-CARE), which is responsible for managing the atomic and renewable energy deployment. A key objective is to localize the manufacture of key components in order to capture most of the value created in the country. However, the creation of real industry requires technology transfer, education and increased public awareness, just to name a few.

The natural and geographic characteristics of Saudi Arabia make it one of the best regions of the world in terms of the amount of solar radiation. According to data from NASA, Saudi Arabia is the "second sunniest place on earth,"

behind Chile's Atacama Desert, with solar irradiation levels along the Red Sea coastline north of Jeddah as high as 8.6 Kilowatts-hour per square meter per day (KWh/m²/day). Such high radiation levels are important in ensuring that utilizing solar energy is economically feasible. The goal of the King Abdullah Initiative is to produce fresh water at cost below 1.5 Saudi Riyals per cubic meter, which is less than half the cost of producing fresh water today from diesel using thermal methods, or through reverse osmosis (RO). Turning toward green technology to increase water desalination capacity hence constitutes a strategic move for the future of the country.

Al-Khafji project, expected to be completed by 2014, is the first phase of the King Abdullah's Water Desalination Initiative. At 30,000 cubic meters of water per day, this will be the largest solar desalination plant in the world, and will meet the fresh water needs of approximately 100,000 dwellers of Al-Khafji city. The project will utilize a combination of two technologies: i) poly crystalline silicon flat photovoltaic panels that are mounted on dual-axis tracking to increase the energy production, and ii) ultra-high concentration photovoltaic (UHCPV) panels, which are also mounted on dual-axis trackers. The poly crystalline silicon panels, being the oldest and most established technology, will represent the bulk of the 10MW installation with some UHCPV systems deployed more for experimental purposes. The silicon panels are manufactured at KACST, while the UHCPV systems use state-of-the-art PV technology that was developed jointly by KACST and IBM Research Center in Yorktown Height, NY. The silicon panels have efficiency of 14 percent, while that of the UHCPV panels is more than double. One reason for using the silicon panels to generate the bulk of the electricity for this project is that Al-Khafji location has more global horizontal solar radiation, and low level of direct solar radiation. UHCPV panels can only convert direct solar radiation while silicon panels convert global solar radiation, which is a mix of direct and diffuse.

potential for low emissions of local pollutants and of greenhouse gases, as well as the energy security benefits arising from being able to shift transportation from oil dependence (Larson, E., et al., 2012).

Fluid hydrocarbon fuels Derived from Non-petroleum Feedstocks offer a much cleaner means of providing cooking services than solid fuels. Clean cooking fuels

can also be produced from coal and/or biomass via the F-T or methanol-to-gasoline processes.

b. Nuclear Power

Most importantly, because nuclear power can provide energy without emitting conventional air pollutants and greenhouse gases, it is worth exploring if advanced technologies could offer simultaneously



Al-Khafji project will use the excess electricity generated from the solar panels during daytime to feed the electric grid. At night time, electricity will be obtained from the grid. As such, there is no energy storage requirement, and also the variability of electric output due to variations in weather conditions during daytime will not play a factor in the operation of the plant or in its economics. A total of approximately 1500 trackers will be used, which will carry solar panels, where each solar panel is rated at 240 Watts under standard test conditions. These silicon panels have met necessary certification requirements, and are designed to survive for 25 years with minimal degradation under conditions that span from -40°C to $+90^{\circ}\text{C}$ ambient temperature. The panels will be connected to central inverters to convert the DC current generated from the panels to AC current that can then be fed into the grid.

Water desalination will take place by implementing a state-of-the-art nanotechnology for reverse osmosis that was developed jointly by KACST and IBM Research Center. This RO membrane technology is highly resistance to chlorine, salt blockage, high flux, and accumulation of bacteria. The new membrane was named (i-Phobe) for its unique chemical composition of hydrophobic ions, which allows

it to change radically when used in different conditions, transforming it into hydrophilic. The new nanomembrane has been developed to efficiently purify water from salts and toxic materials at high flux. It can also resist chlorine and prevent the accumulation of bacteria.

The second phase of the solar desalination initiative will provide 300,000 cubic meters per day of fresh water. Site selection and testing of UHCPV are underway in west coast of Saudi Arabia, where high irradiance solar radiation is more economical for such a system, while a full-scale implementation of solar desalination will be applied in the entire Kingdom. Second and third phases are targeted for 2032. The experience and lessons learned from the first project will be key to the success of this ambitious initiative.

The vision for using solar energy in Saudi Arabia for water desalination is a relevant indicator that resorting to green and sustainable solutions has become a pressing global need, even in the world's most oil-rich countries.

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lower costs, boost public confidence in the safety of nuclear reactors, assure that peaceful nuclear programs are not used for military purposes, and demonstrate effective nuclear waste management practices (UNDP, UNDESA & WEC, 2004).

The widespread interest in nuclear power reflects a broadly shared perception of the need to shift away from fossil fuels because of concerns about climate

change (Hipple et al., 2012). In some countries, such as Egypt, nuclear power also is seen as a way to reduce the dependence on depleted oil and gas or on imported fuels.

In terms of countries GDP and national grid capacity, only Arab countries that pass both a US\$50 billion annual GDP and a 5-GWe grid capacity screening requirement could plan for acquiring a

SHAMS-1 IN ABU DHABI

World's Largest Concentrated Solar Power Plant

Shams1 solar power station is a 100MW concentrated solar power (CSP) plant located in the western region of Abu Dhabi, U.A.E.

Covering an area of 2.5 square kilometers (km²), the equivalent of 285 football fields, Shams1 is the largest CSP plant in operation in the world, and the first utility-scale renewable energy power facility in Abu Dhabi. The plant, which was inaugurated in March 2013 and took three years to build at a cost of US\$600 million, is expected to be followed by Shams2 and Shams3 stations.

Using parabolic trough technology, with more than 258,000 mirrors mounted on 768 solar collector assembly units, Shams1 generates electricity to power 20,000 homes in the UAE. It displaces 175,000 tons of CO₂ per year, equivalent to planting 1.5 million trees or taking approximately 15,000 cars off the road.

By concentrating heat from direct sunlight onto oil-filled pipes, Shams1 produces steam, which drives a turbine and generates electricity. In addition, the solar project uses a booster to heat steam as it enters the turbine to dramatically increase the cycle's efficiency. The project also includes a dry-cooling system that significantly reduces water consumption, which is a critical advantage in the arid desert of western Abu Dhabi.

The plant is developed by Shams Power Company PJSC, a special purpose vehicle owned 60% by Masdar, Abu Dhabi's renewable energy company, 20% by Total, French energy company, and 20% by Abengoa Solar, Spain's solar energy infrastructure company.

Shams1 is an example of collaboration among companies which can achieve large-scale, clean-energy solutions that help meet the world's growing energy demands.

Al-Bia Wal-Tanmia magazine

first nuclear power plant. Even though the threshold size for a grid required to support a nuclear power reactor has been reduced to 5 GWe, to allow for the possibility of a doubling of the grid capacity before the first nuclear power plant comes online, the grid requirement appears to be the most stringent.

IV. ROLE OF CCS IN FUTURE GHG EMISSIONS MITIGATION

The only technology available to mitigate GHG emissions from large-scale fossil fuel usage is CO₂ Capture and Storage (CCS) (Benson et al., 2012).

Over the longer term, CCS could be used to reduce emissions from sources that are difficult to eliminate in any other way, such as energy intensive industrial processes, natural gas cleanup, hydrogen production, fossil fuel refining, petrochemical industries, and steel and cement manufacturing. The availability of scalable CCS technology by 2020 to 2030 would be most beneficial to providing low-emission energy services from fossil fuels while alternatives are still being developed and scaled-up to meet current and growing energy demands (IPCC, 2007d).

CO₂ EOR (Enhanced Oil Recovery) with CCS is widely regarded as an "early opportunity" to demonstrate the viability of CCS as a climate change mitigation option.⁽³⁾ CO₂ EOR is often referred to as a "win win" technology both in terms of improving recovery factors from oil fields, with the associated economic benefits, and mitigating climate change⁽⁴⁾ (Heidug, 2012).

The In Salah (Ain Salah) Project in Algeria, initiated by BP, Sonatreh, and Statoil, is the most technologically complex carbon storage project undertaken to date. CO₂ separated from natural gas is pumped back into the flanks of the gas reservoir from which the CO₂ is produced. Due to the low permeability of the reservoir rocks, three horizontal wells (with open intervals of 1000–1500 m) are used to inject CO₂ into the 20-meter thick reservoir at a depth of about 1800 m. Since 2004, about 0.7 MtCO₂ /yr have been injected into the reservoir (BRGM, 2009).

In general, those regions with large fossil fuel resources, particularly oil and gas, have the largest storage potential. Given the abundance of oil and natural gas resources in the Arab region (and its lack of coal resources), applications of CCS would be mostly limited to storage from fuel transformation,



and natural gas-fueled power plants (Bedrous, M. A., 2007). In the North Africa Arab countries the main potential for capture is in Algeria, Libya, and to a lesser degree Tunisia, while in Egypt efforts have just started to explore CCS opportunities.⁽⁵⁾ Both In Salah Gas and Gassi-Touil projects in Algeria have CO₂ content as high as 10 percent with nearby storage reservoirs (Benson et al., 2012). In Libya most of the potential is from offshore fields which can use CO₂ for EOR, while in Tunisia the largest gas field in the country (Miskar) has nearly 13 percent CO₂ content. In the Middle East 60 percent of the proven gas reserves have more than 100 ppm of H₂S and/or 2 percent CO₂ (IEA, 2008b). Other opportunities for capture in the areas are in fuel transformation, particularly gas-to-liquids, as well as in the growth of gas-fired power plants, and in the developing petrochemical sector.

While no detailed study of storage potential has been made in the area, the global assessment performed points to a highly favorable sedimentary environment for the MENA region (which includes 17 Arab countries, in addition to Iran, Turkey and Israel). The Middle East represents the largest future potential for storage in depleted fields, with the five biggest sites having a combined 180 Gt of capacity.

The combined storage capacity ranges for the MENA region are estimated at 200–1200 Gt for oil and gas fields and 50–550 Gt for saline formations (IEA, 2008a).

In November 2007, the Organization of Petroleum Exporting Countries (OPEC) announced pledges for a US\$ 750 million fund to develop clean energy technologies, in particular CCS, with the participation of Saudi Arabia, Kuwait, Qatar, and the United Arab Emirates. Several initiatives have been started in the region to develop technological capabilities, including the Masdar project, and the recently created Qatar Carbonates and Carbon Storage Research Centre. Many international workshops have been convened in the region to increase awareness and assess which areas of research are most appropriate in the Middle East context. Efforts to promote technology transfer in the region have been led by the Society of Petroleum Engineers and other professional societies, along with OPEC and national organizations (Benson et al., 2012).

The Arab region has the highest potential incremental recovery from CO₂-EOR, with estimates of additional volumes of oil ranging from 80–120 Billion barrels (IEA, 2008a). Given

the lack of availability of CO₂ and the incremental cost, attempts to develop this tertiary method in the region are still limited. In 2009 Saudi Arabia announced plans for a CO₂-pilot project in a water flood of the Arab-D reservoir (Ghawar field) that could be started soon with the injection of 0.8 MtCO₂/yr. In the United Arab Emirates, a pilot project (the first in the Middle East) was started by Abu Dhabi Company for Onshore Oil Operations (ADCO) at the end of 2009 for the injection of CO₂ in the Northeast Bab's Rumaitha carbonate reservoir, while a study was launched in 2010 to use CO₂ for EOR in the Lower Zakum oil field in Abu Dhabi (Benson et al., 2012). Also, the Abu Dhabi Future Energy Company (MASDAR) confirmed plans for a major initiative to reduce emissions from UAE by half using CCS. This CCS project has already launched a pilot plant project in which CO₂ is captured from a source and is being injected in one of the oil reservoirs. The project involves close collaboration between the Masdar Institute, Abu Dhabi National Oil Company and its subsidiaries, the Petroleum Institute, and other academic and industrial collaborators from around the world. The first phase of the project would involve the capture of up to 5 Mt CO₂ /yr from three sources (a gas-fired power plant, a steel mill in Mussafah, and an aluminum smelter at Taweelah). The plan also includes the development of a specific pipeline network and the injection in Abu Dhabi National Oil Company's oilfields.

The Arab region has ample and widely distributed storage capacity, which would allow matching sources and sinks relatively easily. What remains to be determined is the potential for the region to host the emissions from nearby European sources.

V. ARAB MITIGATION EFFORTS AND THE GLOBAL CARBON MARKET

The global market includes a range of instruments used to monetize the CO₂ offset value of climate mitigation projects. According to the UNFCCC, the primary carbon markets associated with actual emission reductions include the Clean Development Mechanism (CDM), joint implementation (JI), and voluntary transactions.

The CDM enables Annex I countries to support the development of projects to reduce GHG emissions within developing countries. As of June 2013, a total

of 6936 projects were registered, and 71 percent of these were for energy industries (renewable/non-renewable) projects (cdm.unfccc.int).

CDM projects are considered an additional revenue source based on carbon credit sales. The Arab region is an attractive CDM destination as it is rich in renewable energy resources and has a robust oil and gas industry. Surprisingly, Arab countries host very few and declining number of CDM projects with only 47 projects registered till June 2012 (Ernst & Young, 2013). The region accounts for only 0.68 percent of global CDM projects and only around two percent of emission reduction credits. The two main challenges facing many of these projects are: weak capacity in most countries for identifying, developing and implementing carbon finance projects, and securing underlying finance. The registered CDM projects in the Arab countries are primarily located in UAE, Egypt, Jordan, Morocco, Qatar, Syria and Tunisia (see Table-7). Other countries in the region, like Saudi Arabia, Bahrain and Oman, are also exploring opportunities for implementing projects that could be registered under the Kyoto Protocol (Salman Zafar, 2013).

Potential CDM activities could thus be initiated in areas such as energy efficiency, renewable energy applications, industrial efficiency, waste management, industrial processes, cement industry, landfills, the agricultural sector and land use change. Energy-efficiency projects in Egypt and the GCC countries, for instance, could save millions of dollars and reduce tons of CO₂ emissions while qualifying as CDM projects. In addition, renewable energy, particularly solar and wind, holds a great potential for the region, similar to biomass in Asia (Salman Zafar, 2013). In the long term, the region could potentially shift from exporting fossil fuel to exporting clean energy to the rest of the neighboring countries.

Egypt, Saudi Arabia and other OPEC countries have successfully negotiated for the inclusion of CCS as a Clean Development Mechanism, allowing developed countries to offset their emissions.

Nationally Appropriate Mitigation Actions (NAMAs) was considered further. NAMAs could include unilateral pledges made by non-Annex I countries that would receive international climate finance support from various sources such as those

SMART GRID AND ELECTRICAL VEHICLES IN THE GCC COUNTRIES

Wajdi Ahmad and Lana El Chaar

Smart grid has recently caught the interest of governments and utilities alike, stemming from several challenges facing global economies. Power generation sector stands as the highest contributor to greenhouse gas (GHG) emissions, followed by the transportation sector. One way to reduce GHG emissions from power generation is through the introduction of distributed renewable energy resources into the energy mix such as wind and solar. Employing the advances in information and communication technologies will smarten the grid and can potentially reduce outages that may occur. At the same time, many communities are embarking on the introduction of Electric Vehicles (EVs) into their transportation systems in order to improve air quality by reducing tank-to-wheel emissions. Compared to internal combustion engine vehicles, EVs can reduce GHG by up to 34% if the power comes from coal-fired power plants and by 60% if the plant runs on natural gas, according to a study from the Electric Power Research Institute (EPRI) and the Natural Resources Defense Council (NRDC). Such choices seem attractive to the Gulf Cooperation Council (GCC) countries, which stand among the highest in CO₂ emissions per capita on a global scale. The GCC countries' population and industrialization growth, in addition to harsh hot and humid weather leading to liberal usage of decentralized air conditioning systems, have caused a sharp increase in electricity demand; hence upsurge of fossil fueled based power generation which in turn has led to high carbon emissions. Furthermore, the rise in population naturally has a great impact on the transportation sector by incrementing the number of cars on the roads emitting higher GHG. Emissions from the transportation sector in the Middle East countries, including GCC, are estimated to double by 2030.

To generate a clearer understanding on how conventional vehicles produce carbon emissions, consider the following example. As the amount of CO₂ produced from burning one liter of fuel is 2.3kg/L, and if the car travels an average of 20,000km/year, the average quantity of fuel used per year is approximately 1428L. Hence, the total CO₂ emissions produced is estimated at 3284kg per car. If 10,000 conventional cars are switched to EVs, an amount of about 33,000 tonnes/annum of CO₂ can be eliminated. It should be emphasized that such emissions are commonly referred to as tail pipe, or "Tank-to-Wheel" emissions, i.e emissions caused by internal combustion in engines. EVs do not have tail pipe emissions, as they



are propelled by electric motors powered by batteries. However, EVs have a "long tail pipe" that extends all the way to the power plant that generates the electricity required to charge the batteries. The process of generating this electricity is associated with CO₂ emission, commonly referred to as "Well-to-Tank" emissions. In order to minimize such emissions, the use of green and clean energy sources for power generation, needed for battery charging, is necessary.

It should be noted that using renewable energy to charge the EV would eliminate the total, i.e. well-to-wheel emissions. This is in fact a great prospect for the GCC region due to the abundant solar power available that until now has been largely untapped.

The GCC region has a golden opportunity to improve its green image through mass deployment of electric vehicle projects. Moreover, due to their zero noise emissions and engine free characteristics, where no oil change / dumping are required, a cleaner and quieter environment is achieved. Furthermore, with the noted recurrent summer high peak demand in the Gulf region, EVs can be leveraged as a source of energy ultimately helping in matching supply and demand during peak load hour, via so-called vehicle-to-grid (V2G) power supply.

The GCC region has a great potential to achieve sustainability through adoption of smart grid technologies and integration of EV into the transportation system. Utilizing solar energy for EV charging would reduce carbon emission remarkably and help promote low-carbon economy. Mass deployment of EV requires a clear vision, a policy of incentives, public awareness, grid reinforcement, charging infrastructure, and smart solution to manage the charging activity.

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TABLE 7 EXAMPLE OF REGISTERED SINGLE CDM PROJECTS AND EMISSIONS REDUCTIONS

Registered CDM Projects (single projects)	Country	ktCO ₂ e/yr 2008-2012
Essaouira wind power project	Morocco	156
Tetouan Wind Farm Project for Lafarge Cement Plant	Morocco	29
"Photovoltaic kits to light up rural households in Morocco"	Morocco	39
Djebel Chekir Landfill Gas Recovery and Raring Project - Tunisia	Tunisia	370
Catalytic N ₂ O destruction project in the tail gas of the Nitric Acid Plant of Abu Qir Fertilizer Co.	Egypt	1066
Onyx Alexandria Landfill Gas Capture and Flaring Project	Egypt	371
Landfill Gas Recovery and Flaring for 9 bundled landfills in Tunisia	Tunisia	318
Zafarana - JICA 120MW Wind Power Plant Project	Egypt	249
Egyptian Brick Factory GHG Reduction Project	Egypt	430
OULJA Landfill gas recovery and flaring	Morocco	32
Waste Gas-based Cogeneration Project at Alexandria Carbon Black Co., Egypt	Egypt	110
Fuel Switching Project of the Aqaba Thermal Power Station (ATPS)	Jordan	397
Dir Baalbeh Landfill Gas Capture Project in Horns	Syria	68
Surac Bagasse Plant Project	Morocco	32
Tal Dman Landfill Gas Capture Project in Aleppo	Syria	65
Reduction of Methane Emissions from Ruseifeh Landfill	Jordan	37
Zafarana K&W IV 80 MW Wind Farm Project, Egypt	Egypt	172
Zafarana 8 –Danida 120MW Wind Power Plant Project, Egypt	Egypt	210
Emissions reduction through partial substitution of fossil fuels with renewable plantation biomass and biomass residues in CEMEX Assiut Cement Plant	Egypt	417
Catalytic N ₂ O abatement project in the tail gas of the nitric acid production plant in G.F.C., Syria	Syria	188
Fuel Switching from Mazout to Natural Gas in Misr Fine Spinning & Weaving and Misr Beida Dyers at Kafr El Dawar	Egypt	45
Tanger wind power project.	Morocco	334

Source: UNFCCC (2013). <cdm.unfccc.int>.

listed above. As such, NAMAs could provide a potential incentive to Arab countries to develop CO₂ EOR with CCS, using co-finance from donors (Heidug, 2012).

VI. CONCLUSION AND RECOMMENDATIONS

The key for Arab countries to mitigation options of climate change is to lay a sound foundation for further evolution to low carbon energy systems.

Because the climate security objective is strongly normative, future energy supply pathways suggest that all the energy sustainability targets can be reached, if appropriate policies are introduced and energy investments are scaled up properly.

Pathways to achieve high CO₂ mitigation levels comprise the following:

- Widespread diffusion of zero- and low-carbon energy supply technologies, with substantial reductions in energy intensity.

- Comprehensive mitigation efforts covering all major emitters.
- Technology and Financial transfers from industrialized countries to support decarbonization.

Most policies that aim at a more sustainable energy supply rest upon four main pillars: more efficient use of energy, especially at the point of end use; increased utilization of renewable energy as a substitute for non-renewable energy resources; accelerated development and deployment of new energy technologies – particularly next-generation fossil fuel technologies that produce near-zero harmful emissions and open up opportunities for CO₂ sequestration, in addition to the new generations of nuclear power; and bio sequestration of carbon in terrestrial ecosystems, including soils and biota.

As a means for potentially decoupling energy demand from economic growth, energy efficiency represents a central lever for policymakers to target. The degree to which efficiency improvements can limit energy demand growth is – by design – one of the main distinguishing characteristics of the pathways. It is possible to improve energy intensity radically through a combination of behavioral changes and the rapid introduction of stringent efficiency regulations, technology standards, and environmental externality pricing, which mitigates rebound effects.

Renewable energy (RE) technologies will play a very important role in reducing GHG emissions, but they alone would not suffice to keep climate change manageable. RE may provide a number of opportunities and cannot only address climate change mitigation but may also address sustainable and equitable economic development, energy access, secure energy supply and reduce local environmental and health impacts.

In addition, the emphasis in Arab countries should be on replacing or upgrading obsolete infrastructure, e.g., via upgrading sites of old fossil fuel power plants with technologies offering additional capabilities and pursuing CCS retrofits. There are four key technology-related requirements essential for transforming the fossil energy landscape: (i) continued enhancement of energy conversion efficiencies, (ii) carbon capture and storage-CCS, (iii) co-utilization of fossil fuel and biomass in the same

facilities, and (iv) coproduction of multiple energy carriers at the same facilities.

High priority should be given to encouraging early CCS action, because if fossil fuels are to be widely used in a future carbon constrained world (via coproduction and co-processing with biomass or via any other means), this will only be viable only if the option is available to safely store CO₂ in geological media. The international political framework for early CCS action has already been established and the Arab region should be a contributor.

The availability of advanced generations of nuclear reactor types could be important for filling the gap between reducing dependence on fossil fuels and the deployment of renewable energy. They could also be an important contributor in the future energy mix for stabilizing CO₂ levels (Hipple et al., 2012) as energy demand continues to grow in the Arab region.

The private sector will lead in developing and deploying most of the effective approaches, but will need a stable governance framework, facilitation of physical infrastructure, capital investments, and the social cohesion necessary for economic development and poverty reduction, while protecting public health and the environment. Success depends on the implementation of robust, global public-private partnerships that can achieve unprecedented cooperation and integration inside governments, businesses, and between governments and businesses. To have an effect on the changing and growing energy sector, this must happen rapidly.

Finally, new public policies are needed to facilitate in the near term industrial collaborations between companies that would produce simultaneously fuels and electricity. It would be desirable to identify policy instruments that specify performance rather than technology and maximize use of market forces in meeting performance goals.

Reaching almost zero or even negative GHG emissions in the Arab region remains an extremely ambitious task. Although a successful transformation, if found to be technically possible, will require the Arab countries to embark on rapid introduction of policies and measures toward concerted and coordinated efforts to integrate climate change into local and national policy priorities.

REFERENCES

- Abdel Gelil et al. (2011). "Energy" in "Arab Environment.4: Green Economy – Sustainable Transition in a Changing Arab World"; Arab Forum for Environment and Development (AFED), Beirut, Lebanon
- Abdel Gelil (2012). "Sustainable Energy Options" in "Arab Environment.5- Survival Options"; 2012 Report of the Arab Forum for Environment and Development (AFED), Beirut, Lebanon.
- Bedrous, Maher Aziz (2007). "Carbon Capture and Storage: Perspective and Opportunities for the Arab Countries"; Expert Opinion to ESCWA, Beirut, Lebanon.
- Benson, S. et al. (2012). "Carbon Capture and Storage" in GEA; Cambridge University Press, Cambridge, UK.
- BRGM (2009). "CO2 Capture and Storage Projects around the World"; Presented at the 3rd international symposium organised by ADEME, BRGM and IFP on the Capture and geological storage of CO2, "Accelerating deployment".
- DESERTEC Foundation (2011). "Red Paper: An Overview of the DESERTEC Concept"; Hamburg, Germany.
- Egyptian Electricity Holding Company – EEHC (2012). "Statistical Annual Report", Cairo, Egypt.
- Egyptian Environmental Affairs Agency-EEAA (2010). "Egypt Second National Communication Under the United Nations Framework Convention on Climate Change"; Cairo, Egypt.
- Emberson et al. (2012). "Energy and Environment" in GEA; Cambridge University Press, Cambridge, UK.
- Ernst & Young (2013). "Assessment of the Activities, Operations, and Areas of Improvement for the CDM Awareness & Promotion Unit (CDM APU).
- ESMAP (2009). "Tapping a Hidden Resource – Energy Efficiency in the Middle East North Africa", Report No 48329-MNA; Sustainable Development Network, Middle East and North Africa Region, Energy Sector Management Assistance Program, the World Bank, Washington D.C., USA.
- Grubler, A. et al. (2012). "Energy Primer" in GEA; Cambridge University Press, Cambridge, UK..
- Heidug, W. (2012). "Joint IEA-OPEC Workshop on CO2 – Enhanced Oil Recovery with CCS"; International Energy Agency; Kuwait City, 7-8 February.
- Hipple, F. V. et al. (2012). "Nuclear Energy" in GEA; Cambridge University Press, Cambridge, UK.
- IEA (2008c). "Energy Technology Perspectives, Scenarios and Strategies to 2050"; www.iea.org/publications/free_new_Desc.asp?PUBS_ID=2012.
- IEA (2012a). "Key World Energy Statistics"; International Energy Agency (IEA), Paris.
- IEA (2012b). "CO2 Emissions from Fuel Combustion – Highlights".
- IPCC (2007d). "Climate Change 2007: Mitigation of Climate Change"; Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, and L.A. Meyer (eds.), Cambridge University Press.
- IPCC (2011). "Special Report on Renewable Energy Sources and Climate Change Mitigation"; O. Edenhofer et al. (eds.), Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, UK, and New York, NY, USA .
- Larson, E. D., et al. (2012). "Fossil Energy" in GEA; Cambridge University Press, Cambridge, UK.
- Lisa Ryan et al. (2011). "Energy Efficiency Policy"; Energy Efficiency Series, IEA.
- Luciani, G. (2012). "Energy Efficiency Policies in the MEAN Countries"; Princeton University, New Jersey, USA.
- Ministry of Energy, KSA (2010). "Second National Communication: Kingdom of Saudi Arabia"; Kingdom of Saudi Arabia.
- Ministry of Energy, UAE (2010). "Second National Communications to the Conference of the Parties of the United Nations Framework Convention on Climate Change"; United Arab of Emirates.
- Ministry of Environment & Physical Development, Sudan (2003). "Sudan's First National Communications under the United Nations Framework Convention on Climate Change"; Republic of the Sudan.
- Ministry of Environment and Land Planning, Tunisia (2001). "Initial Communication of Tunisia under the United Nations Framework Convention on Climate Change"; Republic of Tunisia.
- Ministry of Environment, Jordan (2009). "Jordan's Second National Communication to the United Nations Framework Convention on Climate Change"; The Hashemite Kingdom of Jordan".
- Ministry of Environment, Lebanon (2011). "Lebanon's Second National Communication to the UNFCCC"; Lebanon.
- Ministry of Environment, State of Qatar (2011). "Initial National Communication to the United Nations Framework Convention on Climate Change"; State of Qatar.
- Ministry of Land Management, Urban Planning, Housing and Environment, Morocco (2001). "First National Communication - United Nations Framework Convention on Climate Change"; Kingdom of Morocco".
- Ministry of State for Environment Affairs, Syria (2010). "Initial National Communication of the Syrian Arab Republic". Syria.
- Patwardhan, A. et al. (2012). "Transition in Energy Systems" in GEA; Cambridge University Press, Cambridge, UK.
- Price and McKane(2009). "Policies and Measures to realize Industrial Energy Efficiency and mitigate Climate Change"; UN Energy (UNIDO, LBNL, IAEA), Vienna.
- Qader, M. R. (2009). "Electricity Consumption and GHG Emissions in GCC Countries"; Applied Studies College, University of Bahrain, Kingdom of Bahrain; Energies 2009, 2, 1201-1213; doi: 10.3390/en 20401201.
- RCREEE (2010). "Policies for Energy Efficiency and Renewable Energy in RCREEE Group of Countries"; Regional Center for Renewable Energy and Energy Efficiency, Cairo, Egypt.
- Salman Zafar (2013). "CDM Projects in MENA Region"; ECOMENA- Powering Sustainable Development in MENA.
- Saygin, D., M. Patel and Gielen, D. (2010). "Global benchmarking for the industrial sector-first steps in application and analysis of competitiveness"; UNIDO, in Preparation, Vienna.
- Schock et al. (2012). "Energy Supply Systems" in GEA; Cambridge University Press, Cambridge, UK.

Turkenburg, W. et al. (2012). "Renewable Energy" in GEA; Cambridge University Press, Cambridge, UK.

UNDP, UNDESA & WEC (2004). "World Energy Assessment-Overview: Energy and the Challenge of Sustainability"; United Nations Development Program, United Nations Development of Economic and Social Affairs and World Energy Council, New York/London.

NOTES

1. Photovoltaic PV-Magazine, 2012 (Source: REN21, 2010).
2. The study is currently being implemented by Masdar in association with Schneider Electric.
3. The Intergovernmental Panel on Climate Change (IPCC) (2005) report Carbon Dioxide Capture and Storage defines early opportunities as projects that [are likely to] "involve CO₂ captured from a high purity, low cost source, the transport of CO₂ over distances of less than 50 km, coupled with CO₂ storage in a value added application such as EOR." For information on CCS application at high purity sources, refer to Zakkour and Cook (2010) (IEA-OPEC, 2012).
4. Each incremental barrel of oil produced in a miscible CO₂ flood typically requires the net injection of between 0.25 and 0.40 tCO₂. Net injection takes account of the CO₂ that is reproduced with the oil and recycled (IEA-OPEC, 2012).
5. In early 2012, the World Bank, under the WBCCS Capacity Building Trust Fund (WBCCSTF) (established in 2009), engaged a consortium of consultants lead by ERM to support in assessing the potential application of CCS technologies and strengthen the institutional capacity for planning, preparing and implementing CCS activities in Egypt. The study comprised three key tasks as follows: (1) Technical and economic assessment of CCS potential in Egypt; (2) Analysis of barriers and steps to overcome them; and (3) Capacity building (EEAA, Egypt, 2013).