LOW-CARBON ENERGY TRANSITIONS IN QATAR AND THE GULF COOPERATION COUNCIL REGION

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EXECUTIVE SUMMARY

The countries of the Gulf Cooperation Council (GCC)[1] comprise some of the world's largest producers of oil and gas. The region holds approximately 40 percent of the world's proven oil reserves and 23.6 percent of the world's proven gas reserves, and Qatar holds the world's third largest natural gas reserves. These economies are also built on the extraction and sale of these resources. Qatar, for instance, relies entirely on oil and natural gas for its primary energy consumption, and revenues from these industries accounted for 58 percent of its GDP in 2011.[2] Oil and gas exports from GCC countries represent approximately 73 percent of their total export earnings, 63 percent of their government revenues and 41 percent of their GDP.[3] Rising oil prices and gas prices over the last decade have translated into strong economic growth in the GCC. Since 2002 the region's economy has tripled in size. However, rising economic prosperity has also highlighted a range of environmental challenges for Qatar and the region. The GCC is home to some of the world's largest polluters—several Gulf countries fall among the top 10 emitters in terms of greenhouse gas (GHG) emissions per capita, with Qatar ranking fifth globally. In addition, energy consumption in Qatar and the other GCC countries is placing increasing pressure on domestic energy supplies, and, combined with robust population and economic growth, energy demand will continue to increase over the next decade.[4]

Global climate change will have environmental, economic, and potentially even political and security impacts on Qatar and the GCC as a whole. Combined with rising population levels, climate change will aggravate existing challenges regarding water scarcity and food security, and raise new challenges through adverse impacts on human health, economic development and the environment. The economic importance of oil and gas makes Qatar and other GCC countries economically vulnerable to global efforts to reduce greenhouse gas emissions.[5] As global action to reduce GHG emissions will necessarily require reduced consumption of fossil fuels, this will affect the region's main economic base—the extraction and export of oil and gas.

While addressing climate change and reducing GHG emissions presents challenges for Qatar and the GCC, it is also an opportunity that could underpin a diversification of Qatar's economy and lead to the development of low-carbon technologies such as carbon capture and storage (CCS), energy efficiency technologies and alternative energy. However, in order for Qatar to become a leader in the development of low-carbon technologies, a number of steps, additional to those already taken, are necessary.

The following report reviews a wide variety of considerations for low-carbon transformation and energy reform in Qatar and the GCC region. This report contains four chapters on climate change, CCS, energy efficiency, and solar and other alternative energies. The climate change chapter outlines the challenges of climate change for Qatar and the GCC. It discusses why a comprehensive climate change policy will produce environmental and energy benefits and how Qatar can design such a policy to underpin the development of clean energy technologies. The other three chapters discuss the main technological and policy developments for these energy technologies in Qatar, the GCC and the world. Each chapter contains specific recommendations for actions that Qatar and the GCC could take to address concerns about GHG emissions while at the same time support the development of a range of new energy sources and technologies that would provide environmental and economic benefits for the region and the world.

The key recommendations from the report are as follows:

Climate Change

- *Get the policy framework right:* Develop a comprehensive climate change policy framework that includes mitigation and adaptation action, and a strategy for engaging with international fora on climate change in ways that strengthen and support Qatar's domestic climate change framework.

- *Create appropriate targets and actions:* Identify a suitable suite of renewable energy activities, and explore the scope for both an energy efficiency target and carbon intensity target that can be linked to international efforts to reduce GHG emissions.

- *Enhance financing climate change action and clean energy technology development:* Develop a fund to finance mitigation and adaptation projects as part of a comprehensive climate change policy framework.

- *Develop climate change technologies:* Expand existing R&D capacity to create new markets for Qatar both regionally and at the international level as a leader in low-carbon technologies.

Carbon Capture and Storage

- *Develop a national CCS program:* Include efforts to map storage sites, develop a legal and regulatory framework for CCS development, and enact policies to address the costs of CCS.

- *Build expertise:* Develop CCS technologies or demonstration projects as well as lessons learned from regional and international efforts.

- *Support financing of CCS:* Explore a role for carbon pricing in Qatar and the GCC as means for improving the economic viability of CCS.

Energy Efficiency

- *Explore a range of policy approaches:* Include information and communication measures, regulations and market-based instruments.

- *Establish efficiency measures:* Include lower energy buildings, efficient appliances and industrial equipment, energy prices, public-private partnerships in the energy industry, new government institutions to oversee efficiency, and utility-driven and utility-led efficiency programs.

- *Support existing research initiatives:* Use existing institutions and resources to develop energy efficiency measures as part of a broader clean energy R&D program, and explore opportunities for new energy management technologies.

Solar and Other Alternative Energy

- *Resource assessment and data collection:* Continue assessment and mapping of renewable energy resources in Qatar and the GCC.
- *Develop renewable requirements:* Create renewable energy standards and milestones to ensure renewable energy deployment.
- *Support region-specific technological research:* Promote selected research topics in niche areas for which the region can provide a comparative advantage.
- *Enact energy-pricing reform:* Reform pricing incrementally by addressing energy subsidies.
- *Support public-private partnerships*: Connect utilities, governments and private sector partners to encourage innovation in areas that suit both government goals and private sector interests.
- *Explore alternative finance:* Explore innovative financing options for renewable energy projects tailored to Qatar and the GCC region.

CHAPTER 1: CLIMATE CHANGE

INTRODUCTION

This chapter provides an overview of the impacts on Qatar and the Gulf Cooperation Council (GCC) region from climate change, the economic implications of global action to reduce GHG emissions on fossil fuel consumption, and the economic challenges and opportunities of climate change policies. The chapter concludes with recommendations as to how Qatar can develop a comprehensive approach to climate change that can make a meaningful contribution to reducing its GHG emissions, taking into account its economic interests in a way that leverages Qatar's strengths in focused areas of clean energy technologies to drive climate change solutions for Qatar, the GCC and the world.

CLIMATE CHANGE: ITS IMPACTS AND CHALLENGES

According to the 2013 Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5), "warming of the climate system is unequivocal," and the rate of increase of global carbon emissions in the first decade of the 21st century has been more rapid than predicted.[6] The report also notes that concentrations of greenhouse gases have increased and that each of the last three decades has been successively warmer than any preceding decade since 1850.[7] In the Northern Hemisphere, 1983-2012 was likely the warmest 30-year period of the last 1,400 years. In addition, the report concludes that it is extremely likely that human activities caused more than half of the observed increase in global mean surface temperature from 1951-2010. The report goes on the say that "human influence on the climate system is clear and has been detected in the warming of the atmosphere and the ocean, in changes to the global water cycle, in reductions of snow and ice cover, in global mean sea level rise and in changes to some climate extremes."[8] In terms of future warming, IPCC scenarios show global surface temperature change by the end of the 21st century exceeding 1.5°C in all but one scenario. The report also points out that warming will continue beyond 2100 under all scenarios apart from one.[9]

A June 2013 World Bank report on climate science, *Turn Down the Heat: Climate Extremes, Regional Impacts, and the Case for Resilience*, stresses that a global increase of 4°C by the end of the century remains a real risk. The report outlines the latest scientific evidence as indicative that current levels of greenhouse gas emissions and future emissions trends will lead to higher 21st century emission levels than previously projected.[10] The report also reaffirms the International Energy Agency's 2012 assessment that, in the absence of further mitigation action, there is a 40 percent chance of warming exceeding 4°C by 2100 and a 10 percent chance of it exceeding 5°C in the same period.[11] The updated United Nations Environment Program (UNEP) *Emissions Gap Report*, released at the UNFCCC Conference of Parties in Doha in December 2012 (COP18), found that current emission trends and pledges are consistent with pathways that will reach warming of 3.5°C to 5°C by 2100.[12]

According to the IPCC AR5, the effects of this level of temperature increase would likely include extreme weather patterns, a substantial rise in sea levels and desertification of large swaths of land.[13] The effects of temperature increases also include an increase in the annual mean precipitation at high latitudes and the equatorial Pacific Ocean, and a decrease in water resources in the mid-latitudes, tropics and semi-arid areas (e.g., the Mediterranean Basin, western United States, southern Africa and northeastern Brazil).

These impacts are expected to trigger migration accompanied by unforeseeable political tensions and potential conflict over strategic natural resources such as water.[14] A 2010 United States Department of Defense report also concluded that climate change could have significant geopolitical impacts around the world, contributing to poverty, environmental degradation and the further weakening of fragile governments. The report stated that climate change will contribute to food and water scarcity, will increase the spread of disease, may spur or exacerbate mass migration, and may act as an accelerant of instability or conflict.[15] Climate change will also increase the risk of species extinction and reduce marine ecosystem and fishery productivity.[16]

Climate Change Implications for the Gulf Cooperation Council Region

Climate change in the Gulf region will have environmental, economic, political and security implications. The Arabian Peninsula is characterized by great variability in seasonal and annual precipitation, as well as extreme temperatures. Combined with rising population levels,[17] climate change will aggravate existing challenges of water scarcity and food security, and raise new challenges through adverse impacts on human health, economic development and the environment.[18]

For instance, regional average temperature increases of 1.8°C by 2040 and 3.6°C by 2070 combined with decreasing precipitation exacerbate the already high levels of desertification in the region, further reducing the availability of arable land and water resources and leading to a higher incidence of drought.[19] These effects will occur in a region with fast-growing populations, the lowest levels of water supplies per capita globally, and high water-consumption rates.[20]

The impact of climate change on rising sea levels will also affect coastlines and marine life in the region and could threaten coastal desalination plants that are an increasingly important source of water for the GCC region. Rising sea levels in the region will increase the salinity of underground water supplies, degrading the land further and reducing regional biodiversity. The low-lying coastal zones of Bahrain, Kuwait, Qatar and the United Arab Emirates, where much of the countries' populations and industries reside, as well as the various artificial islands in the Persian Gulf, will be particularly vulnerable to sea level rise. The projected rise in temperatures and incidence of drought are also expected to increase the frequency of dust storms and sand dune movements, and increase soil erosion. In addition to further exacerbating existing stresses on water supplies, climate change will contribute to air pollution and have negative health impacts.[21]

Climate Change Implications for Qatar

Climate change will impact Qatar by enhancing ecological and physical vulnerabilities as well as economic vulnerabilities. According to Qatar's 2011 National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), climate change presents a dual threat:

"On one hand, like other developing countries with minimal adaptive capacity, Qatar's ecological and human systems are prone to the adverse impacts of climate change. On the other hand, due to its total dependence on the export of carbon-based resources, Qatar's economic welfare and prosperity depends on the outcome of the climate change negotiations which seeks, as an ultimate objective, complete phase out of fossil fuel energy sources from the world energy market."[22]

In terms of physical vulnerabilities, arid regions with high climatic variability like Qatar will experience major effects from climate change. Qatar's annual mean temperature has increased by 0.3°C over the last 40 years according to Qatar climate records,[23] and decreasing levels of precipitation are predicted for the region.[24] Additional physical vulnerabilities exist in the water and agriculture sectors, energy sector, public health, coastal zones and marine environment.

- **Water and agriculture sectors:** Demand for water in Qatar is rising at a rate of 12 percent annually, stemming mainly from industry and population growth as well as an increase in irrigation for agriculture. Domestic water consumption is estimated at 675 liters per capita per day and is met through desalination plants.[25] The combination of increased temperatures and no increase in rainfall will likely result in further desertification and water scarcity. Increased pressure on the desalination process will contribute to increased energy consumption and further GHG emissions.[26]

- **Energy sector:** As the most important sector of the economy, the energy sector will be adversely affected by temperature increases and sea level rise. The majority of the oil, gas, power and water facilities are located either offshore or along the coast. Increases in air and sea water temperature will influence the design values for power and desalination facilities.[27]

- **Public health:** Climate change will result in thermal stress and air quality impacts in Qatar, causing increases in incidences of heat exhaustion and heatstroke cases. Desertification and increases in the concentration of suspended particulate matter will lead to respiratory problems among children, asthmatics and the elderly. Current levels of ozone and photochemical oxidants in Qatar are already high, raising public health concerns that have the potential of worsening with climate change.[28]

- **Coastal zones:** A large proportion of Qatar's industrial investments are located along the coast and offshore, including upstream and downstream oil and gas facilities, petrochemicals factories, oil and gas export terminals, and power- and water-generating facilities. Even small changes in the sea level pose serious threats in terms of land inundation and coastal erosion, impacting population settlements and aquatic resources.[29] According to the Maplecroft Climate Change Vulnerability Index, Qatar is one of three countries, along with Kuwait and Bahrain, in the Arabian Gulf exhibiting "extreme" vulnerability to sea level rise. They have estimated that Qatar is susceptible to inland flooding with 18.2 percent of its land area and 13.7 percent of its population at less than 5 meters above sea level.[30]

- **Marine environment:** Because the Gulf waters surrounding Qatar are shallow, any small increase in temperature will have a profound influence on coastal and marine life. From a climate change perspective, the most vulnerable marine species in Qatar are mangroves, sea grass and corals.[31] Due to limited water exchange, a characteristic of the Arabian Gulf, the sea water is prone to temperature extremes. As a result of high sea temperatures, coral bleaching events occurred in 1996, 1998, 2002 and 2012,[32] thus reducing living coral to as little as 1 percent in shallow areas. Along with the loss of coral is a significant decrease in fish stocks and species richness.[33]

CLIMATE CHANGE AND ENERGY

The Energy Mix in Qatar and the GCC

The largest share of GHG emissions in the Gulf countries originates in the energy sector from electricity and heat production. Approximately 40 percent of the world's proven oil reserves and 23.6 percent of the world's proven gas reserves are located in the Gulf. Oil and gas exports from GCC countries represent approximately 73 percent of total export earnings, roughly 63 percent of government revenues and 41 percent of GDP.[34]

Qatar has the world's third largest natural gas reserve, and its proven reserves of oil were the 13th largest in the world at the end of 2012. Qatar is also a member of OPEC and is a significant net exporter of oil and gas. Although only producing liquefied natural gas (LNG) since 1997, Qatar is now the world's largest exporter and a member of the Gas Exporting Countries Forum (GECF). In 2011, Qatar exported over 4,200 billion cubic feet (Bcf) of natural gas, of which over 80 percent was LNG primarily to Asia and Europe. According to official OPEC data, Qatar was the 10th largest total liquids exporter among the 12 OPEC members in 2011.[35] The oil and gas sector accounted for 58 percent of Qatar's 2011 GDP.[36]

The economic importance of oil and gas makes Qatar and other GCC countries economically vulnerable to global efforts to reduce greenhouse gas emissions.[37] Modeling by the IPCC and OPEC[38] find that, like other OPEC member countries, Qatar's economy would be adversely impacted by measures adopted by industrial countries to reduce their GHG emissions. Specifically, a shift by large economies toward increased fuel efficiency and the development of electric cars could lead to reduced global demand for oil. For example, tighter fuel economy standards have recently been introduced in the U.S., the EU and China,[39] and countries have recently signaled their support for the development of electric vehicles through production and sales targets, and subsidy policies.[40] In addition, "breakthrough" technologies such as longer battery storage could further reduce demand for fossil fuels.

Additionally, a successful outcome from the international climate change negotiations that includes global targets for reducing GHG emissions will further reduce consumption of fossil fuels.[41] However, the projected decrease in Qatar's oil exports and revenues is slightly less than the estimates made for the rest of OPEC countries, due to Qatar's large natural gas reserves and related exports, and its' successful diversification away from oil.[42] As countries introduce policies to encourage a shift away from using coal (mainly in electricity production), coal production is likely to be replaced by natural gas-fired electricity production. This replacement is already happening in the U.S. where the low price of natural gas combined with Environmental Protection Agency (EPA) regulations that make it practically impossible to build any new coal-fired electricity plants has already resulted in increased gas-fired electricity generation. This replacement, combined with increased use of natural gas vehicles (NGV)—powering about 112,000 vehicles in the U.S. and roughly 14.8 million vehicles worldwide[43]—has led to consumption of natural gas in the U.S. increasing by 11 percent between 2009 and 2012.[44] And U.S. natural gas consumption is projected to increase by 23 percent between 2012 and 2040.[45] Moreover, in the U.S., growth in global demand for natural gas[46] combined with strong U.S. domestic production and low natural gas prices relative to other global markets[47] have led to an increase in total U.S. natural gas exports by 63 percent between 2008 and 2012.[48] This example of the growth in natural gas points to potential export growth for Qatar and other gas-producing states in the region leading to a shift away from coal.

Greenhouse Gas Emissions in Qatar and the GCC

Although GCC countries are not the world's largest emitters in terms of total GHG emissions and total GHG emissions per GDP, several Gulf countries fall in the top 10 emitters in terms of GHG emissions per capita (see Table 1).[49]

Table 1: GCC country-specific GHG emissions data, excluding land use, land use change and forestry						
	Total GHG emissions (Millions of tons CO_2 equivalent)	**Global rank**	**Total GHG emissions per GDP** (Tons CO_2 equivalent/ million $GDP)	**Global rank**	**Total GHG emissions per capita** (Tons CO_2 equivalent per capita)	**Global rank**
Saudi Arabia	542.1	18	1573.8	26	19.89	21
UAE	256.4	33	1323.0	37	30.37	9
Kuwait	196.5	39	1294.9	38	65.68	1
Oman	90.4	58	961.8	60	32.26	8
Qatar	74.7	66	806.0	76	42.69	5
Bahrain	34.9	95	608.4	104	27.87	12

World Resources Institute (2010) Climate Analysis Indicators Tool.

For instance, Qatar is the world's fifth largest per-capita emitter, with the bulk of emissions generated by the energy sector (96.5 percent, as shown in Table 2). Qatar relies on oil and natural gas for its primary energy consumption. Almost half of energy-related emissions come from electricity and heat production from gas-fired electricity generators. Industrial processes are the second largest source of GHG emissions in Qatar, generated by the production of cement, steel, ammonia and urea, methanol, methyl tertiary butyl ether (MTBE) and plastics.[50] The transportation sector (comprising road transportation at 88 percent and civil aviation at 12 percent)[51] is the key driver of growth in oil demand, though along with waste, generates the smallest share of GHG emissions in Qatar (see Table 3 for a detailed breakdown). Qatar's GHG emissions will continue to increase as a result of increased production and expanded operations in the oil and gas sector.

Table 2: Sources of GHG emissions by sector (expressed as a percentage of total emissions)					
	Energy	**Industrial processes**	**Agriculture**	**Land use change and forestry**	**Waste**
World	71.6	5.5	13.7	5.9	3.3
Saudi Arabia	87.4	5	2.7	N/A	4.9
UAE	92	4.8	1.1	N/A	2
Kuwait	98	1.3	0.2	N/A	0.4
Oman	94.6	3	1.3	N/A	1
Qatar	96.5	3.5	0.2	N/A	0.6
Bahrain	86.6	2.2	N/A	N/A	11.1

World Resources Institute (2010) Climate Analysis Indicators Tool.

Table 3: Sources of GHG emissions from energy sub-sectors in GCC countries (expressed as a percentage of the total emissions from these sectors)					
Energy sub-sectors	**Electricity & heat production**	**Manufacturing & construction**	**Transportation**	**Other fuel combustion**	**Fugitive emissions**
World	42.8	18.6	17.8	12.9	7.9
Saudi Arabia	54.4	18.6	23.9	1.2	1.8
UAE	33.3	36.3	14.3	3.7	12.4
Kuwait	30.4	6.4	6.2	0.3	56.8
Oman	30.1	10.4	7.3	3.7	48.5
Qatar	46.2	24.4	12.6	3.1	13.6
Bahrain	52.1	29	14	1.2	3.7

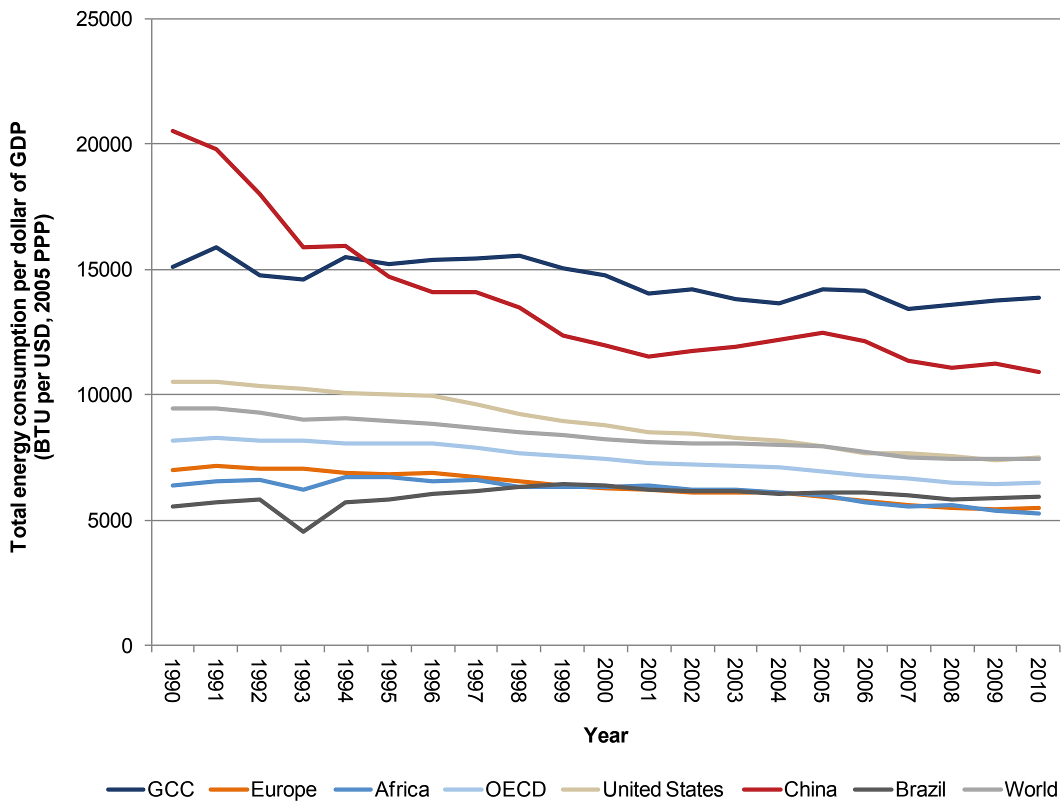
World Resources Institute (2010) Climate Analysis Indicators Tool.

In fact, GCC-wide, the energy sector is the main source of greenhouse gas emissions. Moreover, it is energy used for the production of electricity that drives the majority of emissions. However, in some countries—such as the United Arab Emirates (UAE)—the manufacturing sector is the most significant source of emissions, while most greenhouse gas emissions in Kuwait come from fugitive emissions. The GCC countries' demand for electricity has increased at three times the global average over the last few years due to higher-than-average economic growth rates and huge development projects in the infrastructure sectors, particularly in Saudi Arabia and Kuwait. Consumption of electricity is also high as a result of government energy subsidies, which lead to free electricity in Kuwait and Qatar and very low electricity prices in Saudi Arabia, Bahrain and Oman.[52]

Energy consumption in Qatar and the GCC is also placing increasing pressure on domestic energy supplies. Additionally, the GCC region has the highest energy intensity in the world, and this trend is not expected to change as GCC countries increasingly rely on energy-intensive desalination plants.[53] High levels of consumption combined with robust population and economic growth—30 percent and 56 percent, respectively, from 2000 to 2020—will see energy demand increase over the next decade (Figure 1).[54] And greater domestic consumption of energy will mean that less is available for export. In fact, demand for electricity, which is typically generated by domestic gas, is already outstripping supply in some GCC countries and is expected to rise by 7 to 8 percent per year on average in the coming decade.[55] On current consumption patterns, Saudi Arabia will import about 248 billion liters of gasoline and diesel over the next 10 years, which, at current prices, is worth about $170 billion.[56]

These energy consumptions patterns in the GCC highlight the challenges and opportunities for the region in reducing GHG emissions. As Table 1 shows, Qatar, the UAE, Kuwait and Bahrain have some of the highest per capita CO_2-equivalent emission rates in the world. At the same time, these patterns suggest that there are low-hanging fruit—mitigation options at the low end of the McKinsey Greenhouse Gas Abatement Cost Curve—where measures such as improving waste recycling, building insulation and energy efficiency could have a significant impact on GHG emissions and provide economic benefits.[57]

Figure 1: Trends in energy intensities in different world regions (total energy consumption per dollar of GDP, in BTU per 2005 USD in purchasing power parity)



U.S. EIA (2013) International Energy Statistics.

ACTION TO ADDRESS CLIMATE CHANGE

International Climate Change Initiatives

International efforts to address climate change have been underway for the past few decades under the UNFCCC, as well as in other bilateral and multilateral arrangements. These negotiations have resulted in agreement on a political goal of limiting temperature increases to 2°C above preindustrial levels.

UNFCCC discussions in Copenhagen in 2009 resulted in a non-binding, political declaration of intent for future emission reduction targets, known as the Copenhagen Accord. Significantly, the accord represented a new paradigm where countries agreed to pledge targets (for developed countries) and nationally appropriate mitigation actions (for developing countries) on a bottom-up and voluntary basis. Over 140 countries indicated their support and more than 80 countries provided national mitigation targets or actions. In terms of financial contributions, countries agreed on short-term financing of $30 billion to 2012 and $100 billion in long-term financing by 2020. Subsequent negotiations have resulted in the launch of a second commitment period to the Kyoto Protocol, from 2013 to 2020, and the agreement to negotiate a global agreement with "legal force under the Convention applicable to all parties"[58]—the Durban Platform for Enhanced Action (ADP). This would replace the Kyoto Protocol, cover all countries, be agreed upon by 2015 and implemented in 2020.

However, these negotiations have so far met with only limited success in reaching agreement on commitments by countries to reduce their greenhouse gas emissions consistent with this goal. Recent analysis from the United Nations Environment Programme (UNEP) showed that even if nations meet their current climate pledges, greenhouse gas emissions in 2020 are likely to be 8 to 12 gigatons of CO_2-equivalent ($GtCO_2e$) above the level needed to have a good chance of remaining below 2°C by 2020 on the lowest cost pathway.[59] Similarly, the IPCC's AR5 outlined a carbon budget based on how much CO_2 the world could emit in the future without temperatures rising more than 2°C. The analysis underscored that the amount of carbon the world can burn without heading for dangerous levels of warming is far less than the amount of fossil fuels left in the ground, and at current rates, this "budget" would be exhausted within 30 years.[60]

Parallel to the UNFCCC, climate change issues are being discussed in other groups. The main ones include the Major Economies Forum (MEF), the Group of Twenty (G-20) and the Clean Energy Ministerial (CEM). The Major Economies Forum is a meeting of the largest greenhouse gas emitting countries[61] that seek to address some of the challenging issues of reducing greenhouse gas emissions. The G-20 comprises the world's 20 largest economies[62] and has provided leadership on issues such as climate financing and fossil fuel subsidies. The Clean Energy Ministerial[63] is a global forum for sharing best practices and promoting policies and programs that encourage and facilitate the transition to a global clean energy economy.

While there have been some concerns that these forums might undermine the UNFCCC negotiations, an alternate view is that these forums complement the negotiations by enabling the countries most responsible for greenhouse gas emissions and for financing its mitigation to engage in candid dialogue free of UNFCCC politics, to align parallel domestic initiatives and regulatory approaches, and monitor each other's progress. Progress on climate change issues has been made in these forums.[64] For example, the G-20 agreed to phase out fossil fuel subsidies, which according to the International Monetary Fund (IMF) could reduce global GHG emissions by 13 percent, or 4.2 billion tons.[65] The MEF has developed a Global Partnership on Clean Energy Technologies, which resulted in the creation of 10 "technology action plans" by different countries, outlining the mitigation potential of high priority technologies, highlighting best practices, and suggesting actions countries can take to advance development and deployment of low-carbon technologies.[66]

Climate change issues are also being addressed by a range of other international actors whose primary mandates do not explicitly include climate change. For instance, within the United Nations system alone, some 20 agencies work on climate change-related issues. The implementation of climate change projects is also spread across institutions such as the United Nations Environment Programme (UNEP), the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) and the World Bank.[67]

National Climate Change Actions

Progress globally in addressing climate change also needs to take into account national-level (or even sub-national-level) climate change action. Such action is being driven by concern about the environmental costs of climate change and a goal of developing low-carbon alternatives to fossil fuel energy sources that, in addition, to reducing greenhouse gas emissions, create jobs, develop potentially significant new industries and increase energy security.

For instance, the United States is undertaking state-level action that includes California's emissions trading scheme introduced in 2012 as well as regional efforts to promote emissions trading such as the Western Climate Initiative and the Regional Greenhouse Gas Initiative. Twenty-nine of 50 U.S. states have also adopted renewable portfolio standards (RPS)—accounting for more than 42 percent of electricity sales in the United States. For example, the California RPS has a mandate to expand its renewable portfolio by 33 percent by 2020, and the Colorado RPS was recently updated to a renewable portfolio of 30 percent by 2020 from 20 percent and is anticipated to create an additional $4.3 billion in state revenue.[68] Additionally, Congress established the Advanced Research Projects Agency-Energy (ARPA-E) in 2009 with a focus on transformational energy projects with the potential for advancement with a modest investment. Projects are chosen for their potential to radically improve U.S. economic prosperity, national security and environmental well-being.[69]

China's 12th Five-Year Plan, adopted in 2011, includes policies to reduce the country's energy intensity and CO_2 intensity by 16 percent and 17 percent, respectively, by 2015, and seven regional carbon trading pilot projects are being developed with the goal of gradually establishing a national trading system. The plan also includes renewable energy targets and incentives as well as energy efficiency standards. China's other incentive policies, including the Golden Sun program, which provides financial subsidies, technology support and market incentives to facilitate the development of the solar power industry; and the Suggestions on Promoting Wind Electricity Industry in 2006, which offers preferential policies for wind power development.[70]

South Korea is another country focused on developing a clean technology sector. South Korea's 2009 Framework Act of Low Carbon Green Growth includes provisions for renewable energy incentives and tax shifts to encourage low-carbon economic development. In 2012, the government announced an emissions trading scheme (ETS), which will be implemented in 2015, and has committed to reducing its GHG emissions by 30 percent compared to business as usual by 2020. Energy efficiency policies have been developed to complement the emissions reduction target, and the government is pursuing several strategies in the transport and building sectors, for example, fuel efficiency standards and building design codes. In July 2009, Korea announced a new fuel economy standard for car manufacturers and importers of 17 km per liter, or CO_2 emissions of 140 g per km, by 2015, and a performance-based energy code, which limits total energy use per unit area and was applied to all commercial buildings over 10,000 square meters in July 2011.[71] This is a sample of how countries are using climate change policies to reduce GHG emissions and develop clean technology sectors.

Qatar's Climate Change Initiatives

Qatar is taking a range of actions to reduce its greenhouse gas emissions and to position itself as a leader in the development of climate change and clean energy technologies. Qatar ratified the Kyoto Protocol in 2005 and submitted an initial National

Communication to the UNFCCC in 2011.[72] In 2012, Qatar demonstrated its leadership role and support for global action on climate change action by hosting the 18th Conference of Parties (COP18) to the UNFCCC.

Qatar has also taken a leadership role on climate change in the region and twice hosted the Doha Carbon & Energy Forum (DCEF), a workshop-style conference hosted by the Qatar Foundation, Qatar Petroleum and ExxonMobil and featuring regional, Qatari and international experts from the GCC region's industries, academia and governments. The forum focuses on generating policy recommendations for industry and government on climate change, alternative energy, energy efficiency, and carbon capture and storage.

Domestically, Qatar has a renewable energy goal of sourcing 20 percent of the country's total energy from renewable sources by 2024. The mitigation measures described in the National Communication are also outlined in Qatar National Vision 2030 and include the following initiatives: Qatar Petroleum's corporate objective of achieving zero gas flaring; the state of Qatar's membership in the World Bank greenhouse gas reduction program through its Global Gas Flaring Reduction Partnership;[73] the establishment of formal institutions to manage climate change issues (e.g., the National Committee for Climate Change, a national body tasked with formulating climate policy); the development of public transport systems, including the investigation of electric taxis and compressed natural gas buses, and plans for a mass transport network; and the initiation of a national team on "environmental policies for renewable energy." Qatar also has a national plan for energy efficiency, optimization and resource utilization (QPEERU), which will serve as a driver for the GHG mitigation initiatives under the UNFCCC.[74]

Qatar is also undertaking a range of measures to address environmental challenges that will strengthen its resilience and capacity to adapt to climate change. This includes initiatives by Kahramaa, the national water authority, to reduce the loss of desalinated water and to encourage water recycling and reuse.

Climate Change Technology Development

As noted, developing clean technology should be a focus for Qatar given its resources and opportunity to develop technologies that address specific climate change challenges for Qatar and the GCC, and which could be commercialized globally.

In terms of research and development, Qatar launched the Center for Climate Research during COP18, in partnership with the Potsdam Institute for Climate Impact Research (PIK), with the purpose of studying global climate change and its impacts on ecological, economic and social systems. The institute will work to address remaining knowledge gaps by focusing, in particular, on arid regions—where 2.5 billion people live—and the subtropics. A second key effort of this partnership will be the launch of a Global Climate Change Forum to provide a platform for like-minded countries to work together and create innovative climate change strategies. Stakeholders such as non-governmental organizations with international reach and expertise in the field will also be involved.

Other GCC countries are also providing leadership in the areas of climate change and clean energy, with the creation of a number of research institutions. For example, the UAE has established the Dubai Carbon Center of Excellence and the Masdar Institute of Technology, which focus on alternative energy and environmental engineering. Saudi Arabia has its Center of Research Excellence in Renewable Energy.

Additionally, in 2007, Gulf countries in OPEC pledged $750 million (including $150 million from Qatar) to a new fund to tackle global warming through research for a clean environment, and find technological solutions to climate change, notably carbon capture and storage.[75] The following chapters provide more detailed information on the range of research activities that can contribute to Qatar's climate change and energy goals.

RECOMMENDATIONS

Qatar's climate change action is a combination of firm targets, the most significant being the renewable energy goal and aim for zero gas flaring, which accounts for about 12 percent of Qatar's emissions.[76] Qatar plans on generating 20 percent of its energy from renewables by 2024, and have 1,800 MW of installed green capacity by 2020.[77] Other action is future orientated, such as reducing the energy intensity of electricity consumption, establishing mandatory sustainable building criteria and measures on transportation, and creating legislation under the National Committee for Climate Change (NCCC). Taken together, these actions constitute a blueprint for a comprehensive climate change policy. The following outlines the steps Qatar should take to position itself as a leader in the region on action to reduce GHG emissions and that will underpin the development of clean energy technologies.

Get the Policy Framework Right

It would be beneficial for Qatar to develop a more comprehensive climate change policy under a strengthened National Committee for Climate Change, taking care to consult with stakeholders from government, industry and academia. Experience developing climate change policy in other countries has demonstrated the need for comprehensive understanding of the reasons for these actions to ensure their sustainability and support over time. This is particularly important as the growing impacts of climate change and the failure so far of global efforts to respond will likely require even more stringent and costly mitigation action in the future.[78]

A comprehensive climate change policy framework should include mitigation and adaptation action, and a strategy for engaging with international fora on climate change in ways that strengthen and support Qatar's domestic climate change framework.

Creating a single government agency or an effective interagency process with overall responsibility for climate change issues resting with an identified body would be an important institutional development for Qatar. It would ensure that the impact of climate change action on all economic sectors is fully taken into account. And by providing the decision makers with information on economy-wide impacts and opportunities should ensure an optimal set of climate change policies.

Several countries and regions have already established climate change ministries, including Belgium, Denmark, the EU, Greece, New Zealand, Niue, Romania, Pakistan, Scotland and the United Kingdom. These climate change ministries have been established because the economy-wide implications of climate change policy requires coordination and input across ministries. For example, the U.K. created the Department of Energy and Climate Change (DECC) in 2008 to take over some of the functions related to energy from the Department for Business, Enterprise and Regulatory Reform and those relating to climate change from the Department for Environment, Food and Rural Affairs.[79] Similarly, the Directorate-General for Climate Action (DG-CLIMA) was established by the European Commission in 2010, shifting climate change policy responsibility from the Directorate-

General for Environment. Its mandate is to lead international climate change negotiations, develop and implement legislation to help the EU deal with climate impacts and meet targets for 2020, and implement the EU Emissions Trading Scheme (EU-ETS).[80]

Appropriate Targets and Actions

Qatar has already adopted an economy-wide renewable energy target. The next step will be identifying the suite of renewable energy most suitable for Qatar—more information on Qatar's alternative energy activities is available in Chapter 4 of this report.

Qatar could also enhance these efforts by exploring the scope for both an energy efficiency target and carbon intensity target as other advanced developing countries have done, such as China and India. For instance, an economy-wide energy efficiency target would underpin specific efforts to improve energy efficiency and incentivize investment in developing energy efficient technologies (see Chapter 3 on energy efficiency).

All of these actions should be designed to put Qatar's GHG emissions on an optimal pathway. Such a pathway will need to take into account what other countries of comparable economic development are doing, consider global expectations for mitigation action from Qatar and how this will change over time, and think over how Qatar can use climate change policy to incentivize developments in the energy sector in particular that can produce economic benefits (additional to avoiding the cost of climate change). For instance, reduced domestic energy consumption as a result of energy efficiency improvements will free up gas for export.

The challenge for Qatar will be to reconcile its climate change and environmental sustainability goals with its further development of the energy sector consistent with developing clean energy technologies. For Qatar and the GCC, climate change issues are very much energy issues. And, as discussed, reducing global GHG emissions consistent with achieving the goal of limiting temperature increases to 2°C above preindustrial levels will require reduced consumption of fossil fuels. This creates economic challenges for Qatar and the GCC given their economic dependence on the extraction and export of fossil fuels. However, given Qatar's natural gas resources, the country can play a leadership role in demonstrating the climate change benefits of switching to gas over more carbon-intensive fossil fuels such as coal. Leadership in this area could include developing methodologies comparing greenhouse gas emissions from natural gas and those from coal in electricity generation. In this context, Qatar's goal of zero flaring can help demonstrate the clean energy potential of natural gas, and could lead to developing technologies and know-how that Qatar can export to other gas-producing regions.

Even though current estimates are that natural gas produces approximately 50 percent fewer GHG emissions than coal,[81] achieving a global goal of keeping global warming at 2°C above pre-industrial levels will require, over time, transitioning electricity sectors away from natural gas to renewable energy.[82] Qatar can respond to the 2°C goal now by contributing to the development of both CCS—which can allow for the burning of fossil fuels in a carbon constrained world—and the development of renewable energy technologies (see Chapter 2 on CCS).

Financing Climate Change Action and Clean Energy Technology Development

As part of a broad response to climate change, Qatar should develop a fund to finance mitigation and adaptation projects as part of its comprehensive climate change policy framework. Such an initiative could support domestic climate change and energy goals such as the development of renewable energy projects and climate change technologies. A national climate change fund could follow the model of Brazil, which has established the Brazilian Climate Fund, capitalized by revenues from a special tax on oil production.[83] This model could play an important demonstrative role in the region and, in this regard, any such fund could be expanded into a GCC-wide initiative. By setting up its own national climate fund, Qatar could attract international finance for domestic investments in clean technology and generate revenues through the taxation of existing resources such as in the oil and gas sector.

Further, such a fund should be linked with international climate financing efforts. International climate change finance is channeled through multilateral funds such as the Global Environment Facility (GEF), Climate Investment Funds (CIFs) and Adaptation Fund, as well as through bilateral channels.[84] By either contributing funds to CIF initiatives in other countries or regions or receiving CIF funding for domestic projects, Qatar could guarantee its membership on the CIF's Trust Fund Committee, the body that oversees the operations of the fund, provides strategic direction, and approves and oversees programming and projects.[85] Although it is currently restricted from supporting CCS projects, the Clean Technology Fund (CTF) under the CIFs is relevant to Qatar as it finances projects and programs that contribute to demonstration, deployment and transfer of low-carbon technologies with a significant potential for long-term greenhouse gas emissions savings.[86] Involvement in such international financing initiatives could potentially advance Qatar's ambitions to be a leader in low-carbon technology development.

Developing Climate Change Technologies

Qatar and the GCC region have substantial resources and R&D capabilities that can be used to address climate change. The country's capacity to develop climate change technologies is a key strength and could create new markets for Qatar both regionally and at the international level as a leader in low-carbon technologies.

- **Create a domestic enabling environment:** An important driver of the development of climate change technologies will be Qatar's domestic climate change policy. In this regard, climate change policy should provide the right incentives for the development and deployment of low-carbon technologies.[87] For example, clear targets for renewable energy, CCS and energy efficiency goals will signal to investors an opportunity to develop climate change and energy technologies. Policy certainty is another key factor affecting the investment climate. One need look no further than Australia, where, as a result of the anticipated repeal of the Carbon Pricing Mechanism, "businesses are delaying strategic decisions or investments because they are uncertain about the future existence of a carbon price or the structure of any alternative carbon policy, particularly in the short-term", and "the […] Government must provide longer-term regulatory certainty in the pricing of carbon [to] incentivize business to reduce carbon emissions in the most efficient way and support the transition to a low carbon economy."[88] And in a 2011 survey of U.S. businesses, most respondents cited ambiguity in government support as the key risk associated with low-carbon investments.[89]

Qatar should consider ways to develop greater policy certainty such as locking in its climate change and clean energy commitments by making a political pledge for a post-2020 emission reduction target under the UNFCCC.

- **Develop bilateral cooperation:** Qatar should develop further bilateral cooperation on clean technology, similar to the initiative mentioned above by the Potsdam Institute for Climate Impact Research, and involve both government ministries and research institutions. This could be modeled on bilateral partnerships such as the U.S.-China clean energy partnership, which comprises clean technology energy projects between U.S. Department of Energy laboratories and the Chinese Academy of Sciences on enhanced oil recovery (EOR) for CCS, biomass gasification, and syngas;[90] and the U.S.-China Clean Energy Research Center (CERC), that facilitates joint clean energy R&D on topics such as building energy efficiency, clean coal (including CCS) and clean vehicles.[91]

  Financial contributions by Qatar (discussed below in more detail) could help underpin these partnerships while providing Qatar with access to cutting edge R&D capacity in the U.S. and elsewhere. For instance, the pledge in 2007 by Gulf countries in OPEC of $750 million (including $150 million from Qatar) to a new fund to tackle global warming through research for a clean environment could be a model for developing international climate change and clean energy research partnerships at a government-to-government level.

  GCC-wide cooperation such as the EU-GCC Clean Energy Network—an instrument for the development of cooperation activities on clean energy policy and technology in the areas of renewable energy sources, energy efficiency, clean natural gas, and carbon capture and storage—provides another avenue through which to pursue international cooperation on clean technologies.[92]

- **Engage internationally:** Qatar also has a stake in discussions at the international level and should therefore ensure that international policy efforts maximize the potential for sharing of knowledge and technologies of mutual benefit, for example, through international research-sharing agreements. Supporting international technology-oriented agreements is crucial and an important complement to other international efforts such as emissions-based agreements.[93]

CHAPTER 2: CARBON CAPTURE AND STORAGE

INTRODUCTION

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

THE ROLE OF CARBON CAPTURE AND STORAGE (CCS)

The Role of CCS in Reducing Emissions

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

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

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

The Role of CCS in Qatar and the GCC Region

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

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

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

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

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

BARRIERS TO DEVELOPING CCS

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

Technical Barriers

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

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

Transportation

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

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

Storage

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

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

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

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

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

Financing

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

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

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

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

CCS INITIATIVES

International Forums Working on CCS

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

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

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

International and Bilateral Cooperation on CCS

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

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

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

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

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

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

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

Qatar's Domestic CCS Initiatives

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

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

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

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

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

RECOMMENDATIONS

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

Policy Framework: A National CCS Program for Qatar

A national CCS program could include the following elements:

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

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

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

Build Expertise

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

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

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

Financing for CCS

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

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

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

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

CHAPTER 3: ENERGY EFFICIENCY

INTRODUCTION

This chapter discusses the need for energy efficiency measures in Qatar and the Gulf Cooperation Council (GCC) by providing an overview of energy intensity in the region; the benefits of energy efficiency measures including different types of technologies that can be applied; lessons learned at the international level by way of policies and obstacles; and financing for energy efficiency. The chapter also reviews existing energy efficiency measures in Qatar and the GCC, and concludes by providing recommendations for policy approaches and efficiency measures tailored to the region.

GULF COOPERATION COUNCIL REGION'S ENERGY INTENSITY

The GCC Energy Mix in a Global Context

The GCC region has the highest energy intensity in the world, and member states are expected to post robust growth in population, GDP and energy use over the next decade. Driven by economic expansion and development, many GCC countries are likely to see dramatic rises in the fraction of energy that is consumed domestically and unavailable for export. Rising living standards and increasing dependence on energy-intensive desalination processes compound the energy challenges for the GCC. For both economic and sociopolitical reasons, energy prices in GCC member states are well below international benchmarks. This has reduced incentives to invest in energy efficient infrastructure and equipment. For example, electricity is free to Qatari nationals. In Saudi Arabia, prices are only approximately 1.3 cents/kWh for residential customers up to 2,000 kWh per month, and 3.2 cents/kWh for industrial customers.[138] Bahrain, with relatively modest hydrocarbon resources, charges residential customers using less than 2,000 kWh per month only 0.8 cents/kWh.[139] In comparison, the average residential electricity prices are approximately 12 cents/kWh in the United States, 25 cents/kWh in the European Union, 9 cents/kWh in China, 28 cents/kWh in Brazil, and 8 cents/kWh in South Africa.[140]

Low energy and electricity prices are not only contributing to strong energy demand growth but also are encouraging investment in inefficient, long-lived infrastructure. In many cases, investment in inefficient transportation, buildings and industrial infrastructure has a lock-in effect that makes it difficult to reduce energy intensity and improve energy efficiency. This intensive use of fossil fuel energy contributes to greenhouse gas emissions and, as a consequence, to global climate change. Qatar, the United Arab Emirates (UAE), Kuwait and Bahrain have some of the highest per capita CO_2 emission rates in the world. Qatar's economy, for example, emits approximately 42 tons of CO_2 per capita per year, more than 10 times above the world average of 4.6 tons (see Table 1 in Chapter 1 for more information).[141]

A Changing Energy Landscape

Nevertheless, many world regions, including the GCC, are investing in alternative fuels and energy efficiency, as well as in unconventional resources such as shale gas. The natural gas boom has fueled additional energy efficiency opportunities: the replacement of existing industrial coal boilers and process heaters with new efficient natural gas boilers, as well as direct use of natural gas in residential heating, cooling and hot water systems all offer significant full-fuel-cycle efficiency improvements.

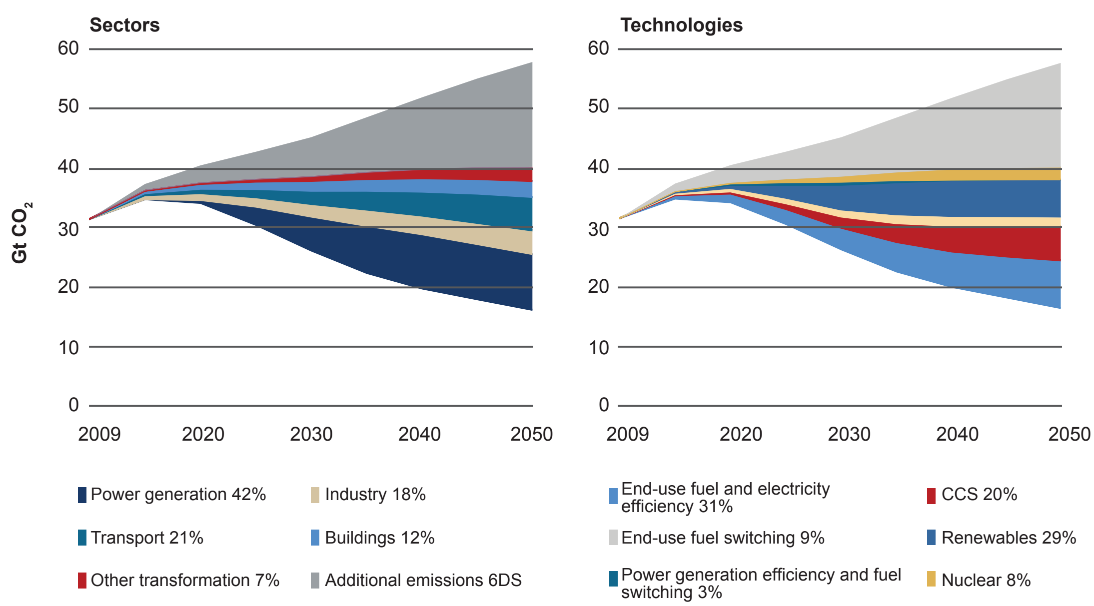
BENEFITS OF ENERGY EFFICIENCY MEASURES

Technology

New technologies, unconventional resources, increasing stringency of energy and environmental policies, and new transportation options will likely increase competition in energy markets. Efficiency improvements can reduce the need for energy imports, maximize fuel exports, increase supply reliability, improve industrial competitiveness, and reduce production and energy costs to consumers. In addition, energy efficiency options represent 40 percent of global greenhouse gas reduction potential that can be realized at a cost of less than $80 per metric ton of carbon dioxide equivalent (tCO_2e) (Figure 2).[142]

Figure 2: Global contributions to emissions reductions in the 2°C scenario, by sector and technology

Energy efficiency investments provide a large contribution to emissions savings—approximately 40 percent—due to their low cost and high returns.



Energy Technology Perspectives 2012: Global contributions to emissions reductions in the 2°C scenario, by sector and technology © OECD/IEA, 2012, fig. 1.9, p. 39.

Investments

Energy efficiency investments in buildings, industry and transport are, in many cases, economically beneficial. Most such investments have short payback periods (see Table 4) with annualized rates of return after 10 years ranging from 30 percent to over 100 percent, and even longer-term payback investments can be profitable because the fuel-cost savings over the lifetime of the capital stock often outweigh the additional capital cost of the efficiency measure. For example, McKinsey projected that $170 billion a year invested in efforts to boost energy efficiency from 2008 to 2020 could halve projected global energy demand growth, and these investments would have an average internal rate of return (IRR) of 17 percent, with each of them generating an IRR of at least 10 percent.[143] Efficiency measures are also often most cost effective when new plants or buildings are being designed and built.[144] Nevertheless, a number of barriers can hamper the deployment of energy efficiency measures. Such barriers can arise from the inability to capture broadly dispersed benefits, uncertainties in quantifying benefits, price distortions in the market (including distortions arising from subsidies) and other causes.

Table 4: Internal rate of returns for 119 studied projects in developing countries

Payback period describes the number of years required to return the investment in full; thereafter, cost savings are essentially pure income. A more familiar method to evaluate investments is by using rates of return on invested capital, which are shown by the IRR columns. Efficiency investments can often have very high investment returns and are essentially risk-free.

Sector	Payback years	IRR 3 years (%)	IRR 4 years (%)	IRR 5 years (%)	IRR 10 years (%)
Automotive/autoparts	1.93	26	37	43	51
Cement/ceramics	2.19	18	29	36	45
Chemicals	2.90	2	14	21	32
Equipment manufacturing	2.10	20	32	38	47
Food and beverages	1.10	74	83	87	91
Metal	1.50	45	55	60	66
Paper	0.90	96	105	108	111

Alcorta et al. (2013) Return on Investment from Industrial Energy Efficiency: Evidence from Developing Countries.

Recent developments in efficient technologies such as LEDs and efficient turbines have increased the number of potentially profitable investments, even in environments with low prevailing energy prices. In cases where the barriers distort investments, governments can employ policies to overcome them. Of course, technological solutions must, at a minimum, be cost effective for societies and nations as a whole. Each of the GCC countries has unique social, political and cultural realities. As such, the solutions for each may be unique, but will be more effective when coordinated and integrated with other national and regional policies.

PROBLEMS AND POLICIES: INTERNATIONAL EXPERIENCE WITH ENERGY EFFICIENCY

Energy efficiency investments can be highly profitable because they can save money for companies or individuals by lowering energy costs. Nevertheless, many efficiency opportunities go untapped owing to obstacles that have historically reduced interest or profitability in such projects. This section describes some of those obstacles and policy options to address them.

Market Distortion through Energy Subsidies

Energy subsidies distort the cost-benefit calculations of individual investors and are therefore one of the biggest obstacles to efficiency investment. Subsidies are often rooted in a wide variety of well-meaning goals, such as protecting consumers, helping low-income groups gain access to energy, reducing the impacts of international price fluctuations, controlling inflation, distributing resource wealth to the population and helping domestic industries. On the other hand, recent international discussions have highlighted the costs as well. Many international organizations, such as the International Monetary Fund (IMF), World Bank, United Nations Development Programme (UNDP) and others have recently investigated some of the social costs of such subsidies and found that they can aggravate fiscal imbalances, crowd out priority public spending such as education and health, and distort pricing signals and resource allocation.[145] By artificially promoting capital-intensive industries, they depress investment in renewable energy and energy efficiency, and accelerate the depletion of energy resources and the rise in environmental pollution. They are regressive in nature, and most benefits are captured by higher-income households, therefore reinforcing inequality. By encouraging inefficient energy consumption, they also lead to additional greenhouse gas emissions: The IMF estimates that eliminating subsidies—which amount to more than $500 billion annually—would lead to a 13 percent reduction in greenhouse gas emissions below business as usual, or 4.2 billion tons by 2050.[146]

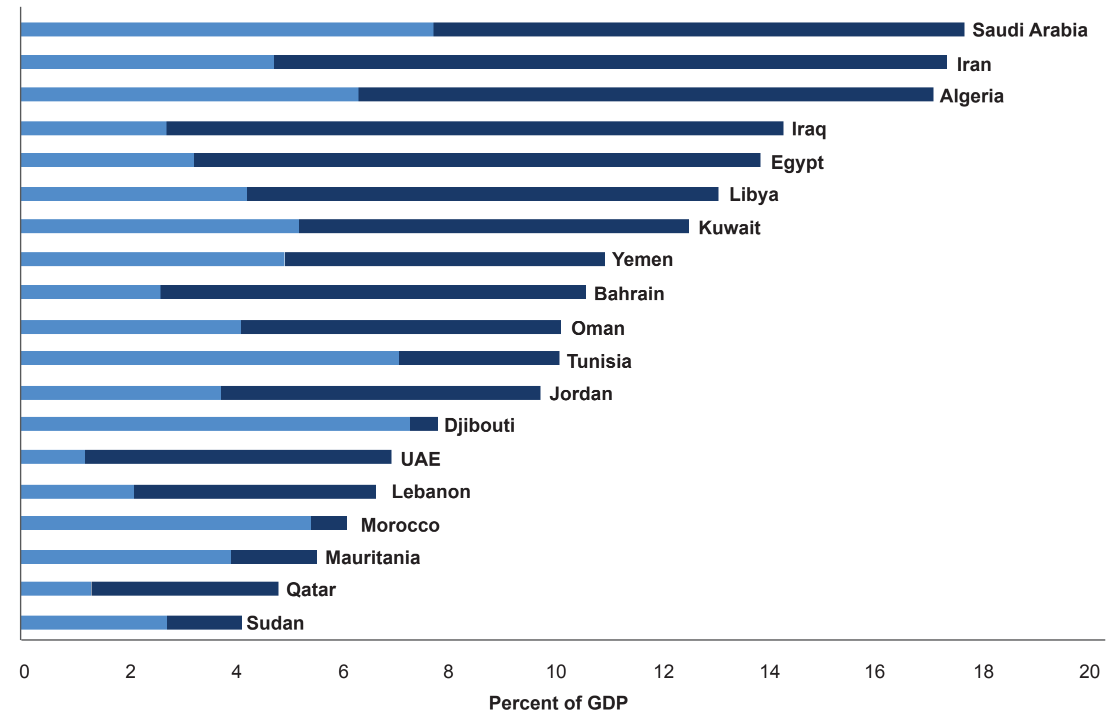
Because of these detrimental effects, there is currently a major international effort to identify and reduce distortionary energy subsidies at the national level.[147] Building on the commitment made at the Pittsburgh G-20 Summit in 2009 to phase out inefficient fossil fuel subsides, G-20 leaders agreed at the recent St. Petersburg Summit on the methodology for a new peer-review process of fossil fuel subsidies. Saudi Arabia's Economy and Planning Minister Mohammed al-Jasser recently said at the Euromoney conference in Riyadh that "[t]his has become an increasingly important issue as these subsidies have become increasingly distorting to our economy. This is something we are trying to address."[148] On July 30, 2013, Latvia's Cabinet of Ministers passed amendments that stipulate a significant reduction in natural gas plants subsidies.[149] Countries such as Turkey, Armenia, the Philippines, Brazil, Chile, Peru, Iran, South Africa, Kenya and Uganda have all attempted energy subsidy reforms.

The Middle East and North Africa (MENA) region accounts for about 50 percent of global pre-tax energy subsidies (see Figure 3). Energy subsidies amounted to over 8.5 percent of regional GDP or 22 percent of total government revenue in 2011. In Kuwait, Qatar, Saudi Arabia and the UAE, energy subsidies accounted for 15.10 percent, 15.39 percent, 31.99 percent, and 28.11 percent of respective government expenditures in 2010.[150] These four countries also have the highest per capita subsidies in the world: UAE, $4,172 per year; Kuwait, $3,729; Qatar, $2,622; and Saudi Arabia, $2,291.[151] Countries in emerging and developing Asia made up over 20 percent of global energy subsidies. They totaled nearly 1 percent of regional GDP or 4 percent of governance revenues.[152]

Non-Market Obstacles to Energy Efficiency

Even in investment contexts in which the price of energy is unsubsidized, some efficiency opportunities remain underdeveloped. Despite the vital role of energy efficiency in cutting energy demand and reducing GHG emissions, there sometimes arises an energy-efficiency gap, also known as the "energy

Figure 3: MENA pre-tax energy subsidies and spending on education [a, b] (in percent of GDP)



This image was taken from the IMF Middle East and Central Asia Department policy brief, "Energy Subsidies in the Middle East and North Africa: Lessons for Reform". Data in this figure has been generated from IMF staff estimates, national authorities, the Organisation for Economic Co-operation and Development, International Energy Agency, Deutsche Gesellschaft für Internationale Zusammenarbeit, IMF "World Economic Outlook", and World Bank.
[a] Includes petroleum, electricity, natural gas, and coal subsidies.
[b] Pre-tax subsidies refer to 2011, education refers to the latest available data.

paradox," whereby energy-efficient technologies with lower lifetime costs diffuse more slowly through the economy than expected given their cost advantages. Sometimes these differences arise from lack of information about savings, and other times result from institutional barriers, split incentives, or challenges in aggregating finance for smaller-scale technologies. Governments around the world have adopted a range of specific policy tools to overcome these obstacles, including targets, mandated standards, labeling programs, tax incentives and others. Some examples of these tools include:

- **Voluntary and information-based initiatives:** These initiatives entail providing information and encouraging consumers to reduce their emissions and can include awareness campaigns, labeling and training programs. Labeling initiatives involve the identification of products associated with low emissions in order to increase consumer knowledge and increase market demand. For example, the Energy Star program in the U.S. identifies energy-efficient products and buildings in order to reduce energy consumption, improve energy security, and reduce pollution through voluntary labeling of or other forms of communication about products and buildings that meet the highest energy efficiency standards.[153]

- **Minimum energy performance standards:** A complement to voluntary labeling is to establish required minimum efficiency standards for appliances, equipment, vehicles and other technologies. Over decades of experience in many countries, this method has proven to be a relatively low-cost way to realize large gains over time, particularly if the standards are periodically revisited and increased as technologies improve. These are increasingly being used in non-OECD economies. For example, in 2000, Ghana's Electrical Appliance Labeling and Standards Program (GEALSP) partnered with CLASP (an nongovernmental organization that helps countries develop and implement standards) and the Ghana Energy Foundation (a public-private partnership) to develop the first standards and labels in sub-Saharan Africa. Ghana first implemented a Minimum Energy Performance Standard (MEPS) for room air conditioners—the first MEPS in sub-Saharan Africa—because of their role in peak electricity demand and because a large part of the air conditioner market is new equipment. Over 30 years, Ghana's air conditioner MEPS is projected to save $64 million in annual energy bills and reduce CO_2 emissions by 2.8 million tons. In 2005, Ghana added a MEPS for compact fluorescent lights and a labeling program for air conditioners and lighting.[154]

- **Building energy codes:** Building energy codes are legal requirements regulating the energy performance of building designs and their compliance during construction. The enforcement of energy codes for new buildings and for alterations to existing buildings is an effective policy instrument to reduce the long-term energy use and potential emissions from buildings. For example, the city of Tianjin, China, has developed residential building energy efficiency codes and requires the use of energy-efficiency building technologies. Developed in 1997, compliance is now close to 100 percent with a payback period of between 5 and 11 years.[155]

- **Regulations for designated consumers:** Regulations for designated consumers are a way for governments to mandate that large energy consumers take steps to understand, monitor and plan their energy use. Examples of common mandated practices for designated consumers include energy audits, energy consumption reporting, the appointment of an energy manager and energy savings plans. These four regulations may be implemented as stand-alone approaches or a part of a comprehensive package. The Indian Energy Conservation Act of 2001 mandates energy audits, consumption reporting, and energy managers for firms in nine economic sectors: power, fertilizer, iron and steel, cement, pulp and paper, aluminum, chloralkali, textiles and railways.[156]

- **Regulations in the public sector:** Governments can establish credibility and bring awareness to energy efficiency through public-sector regulations, as well as build governmental capacity to understand and manage energy-efficiency programs. There are a range of viable, short-term, cost-effective regulations that can save government resources and deliver co-benefits. For example, Uruguay has defined a mandatory public-sector phase out of incandescent lamps, while Mexico is requiring mandatory energy planning and reporting.[157]

Energy Efficiency Finance

High upfront capital costs, high information costs and scale are also barriers to attracting finance. Many major economies have adopted financial and fiscal measures to tackle these hurdles. These steps include subsidies and grants, energy performance contracting (EPC), national/municipal loan/rebate programs for residential and/or commercial energy efficiency, energy utility obligations, mortgage-backed energy efficiency financing, preferential taxes or mortgage rates, utility on-bill financing, such as PAYS (pay as you save), revolving guarantee funds, green banks and climate funds. Some example policies include:

- **Local- or utility-scale efficiency programs:** In the United States, 52 state and 51 local government energy-efficiency programs are now in operation, as well as 103 utility programs that provide financing for homeowners and business in their service territories.[158]

- **National level favorable financing:** China is investing $386.58 billion in key energy efficiency and emission reduction projects in the 12th Five-Year Plan period (2011-2015).[159] Energy efficiency projects with an annual energy savings of more than 5,000 tons of coal equivalent (tce, roughly 15 million KWh) are eligible for government rewards.[160] In addition, energy efficiency projects in China receive preferential treatment in interest rates when borrowing from banks. Moreover, the central government's push for the expansion of "green credit" business is leading banks to create new financial products for energy service companies (ESCOs) such as future receivables from energy efficiency project savings.[161]

- **Funding for efficiency implementation and research:** In Brazil, utilities are required to dedicate 0.5 percent of their income to energy efficiency projects or research. Together they have invested about $378.4 million on such initiatives since 2008, including public awareness campaigns. The national development bank Banco Nacional de Desenvolvimento Econômico e Social is offering an energy efficiency credit line (PROESCO) with an annual rate of 14 percent. About $16.5 million of financing has been approved at this line in 2011.

- **Preferential tax treatment:** In South Africa, the Income Tax Act allows for additional depreciation allowances up to 55 percent for greenfield projects over $19.42 million, where one of the rating criteria being energy efficiency savings. It provides a tax deduction to an energy efficiency taxpayer, with a focus on renewable energy. There are also other tax allowances that provide general depreciation of asset allowance that are applicable not only to ESCOs, but also to any business that meets the energy efficiency savings requirements. In addition, the National Treasury has envisaged a carbon tax that will be implemented in 2013/2014 at the rate of $11.65 per ton of CO_2 on direct emissions and will increase by 10 percent per annum until 2020, which would create an incentive for energy efficiency projects.[162]

- **Multilateral aid to provide lower-cost financing:** Early in 2013, the Inter-American Development Bank (IDB) approved $50 million for the Energy Efficiency Finance Facility to finance companies investing in energy efficiency and self-supply renewable energy projects in Latin America and the Caribbean.[163] In March 2013, development banks in the BRICS nations (Brazil, Russia, India, China and South Africa)—Brazilian Development Bank (BNDES), the Russian Bank of Development and Foreign Economic Affairs (Vnesheconombank), the Export-Import Bank of India, the China Development Bank (CDB) and the Development Bank of Southern Africa (DBSA)—agreed to finance projects connected to sustainability and the low-carbon economy, including investments in renewable energy and energy efficiency.

ENERGY EFFICIENCY POLICY

Recent Developments in Efficiency Policy in Qatar and Other GCC Countries

Many GCC countries have recognized the role for energy efficiency, and some have made substantial investments in this area. Table 5 shows a detailed breakdown of targets and standards for all six GCC countries. A few highlights are discussed in this section, and it should be noted that all GCC countries have begun to investigate and implement policies focused on efficiency.

- **Qatar**'s Vision 2030 and the Qatar National Development Strategy 2011-2016 aim at reducing the energy intensity of electricity consumption through awareness campaigns, standardization and seasonal shutdowns. The strategy seeks to cut total power generation by 7 percent by 2016.[164] Qatar implemented mandatory sustainable building criteria in December 2011. The Qatar Green

Building Council, established in 2009, aims at establishing best practice in sustainable building for Qatar and disseminating knowledge on sustainable living. Within industry, ExxonMobil has joined with Qatar Petroleum to conduct a thorough review of RasGas LNG trains and Al Khaleej Gas plants to monitor plant performance to identify plant and energy efficiency opportunities. ExxonMobil and Qatar Petroleum have also been working together on more efficient LNG ships (Q-Max and Q-Flex), an LNG facility and remote gas detection. Chevron's Center for Sustainable Energy Efficiency (CSEE) at Qatar Science & Technology Park, launched in March 2011, aims at supporting Qatar's sustainable development strategy. Its visitors' center includes training and demonstration of energy-efficient lighting and photovoltaic technologies. Qatar has also sought to halve flaring between 2008 and 2016 to improve energy efficiency and reduce emissions. The $1 billion Jetty Boil-Off Gas Recovery Project at Ras Laffan Industrial City has achieved over 65 percent reduction in flaring from on-plot LNG facilities since 2009. In addition, efforts are underway at the Qatar Sustainable Energy and Water Utilization Initiative, based at Texas A&M University at Qatar, to improve desalination technologies and promote public awareness of sustainable use of energy.

- In **Saudi Arabia**, the government established the Saudi Energy Efficiency Center (SEEC) in 2010 to focus on reducing power through audits, load management, regulation and education. The country is currently developing a Mandatory Energy Efficiency Plan that will include energy conservation targets. Saudi Arabia's Ministry of Water and Electricity created the Energy Conservation and Awareness Department to develop a comprehensive energy conservation plan, with a focus on building awareness among energy users and the general public, and is working with the Saudi Electricity Company to implement energy conservation and load management programs. The ministry rationalizes the use of electricity nationally, imposes limits on the maximum power that can be delivered to electricity consumers and establishes demand-side management actions. Industry in Saudi Arabia has also made efforts to maintain their own efficiency standards, for example, Aramco's energy management program achieved an energy savings of approximately 10,000 barrels of oil equivalent per day in 2011—which represents 3.5 percent of the company's total energy consumption for the year. Calls to revise electricity subsidies have also been raised by Mohammed al-Jasser, economy and planning minister, as well as the Saudi Electricity Company.

- In the **United Arab Emirates**, the Emirates Authority for Standardization and Metrology (ESMA) launched its National Energy Efficiency and Conservation Program in 2011, which seeks to promote energy efficiency in the residential section through massive education campaigns and a labeling system. The UAE continues to invest in energy efficient systems, such as the solar-powered hot water systems currently in use at the Dubai Abattoir in Al Qusais, the Al Quoz cemetery, the Al Fahidi Market and more. Furthermore, new UAE Energy Minister Suhail bin Mohammed Al Mazrouei has called for steps at the federal level to establish tougher building codes, stronger appliance standards, higher vehicle fuel standards and strategic management of water and desalination investment, and Dubai has set a target of a 30 percent cut in energy demand by 2030.

- **Kuwait** has begun the process of mapping a national energy efficiency strategy, supported by the Ministry of Electricity and Water (MEW) and Kuwait National Petroleum Company through the Kuwait Energy & Efficiency Conference.

- Energy efficiency initiatives are still in their infancy in both **Oman** and **Bahrain**, and Qatari initiatives are detailed in the following section.

The GCC region has a number of multilateral and regional institutions that support and promote energy efficiency and related research and development, most notably the GCC Interconnection Authority (GCCIA), a joint stock company subscribed to by all six GCC member states, which aims to become the driver of efficient markets through electricity trading in member states and other regional markets.

Table 5: Energy use targets and standards in GCC countries

National Targets & Standards	GCC	Saudi	UAE	Abu Dhabi	Dubai	Oman	Kuwait	Qatar	Bahrain
Nationwide									
Low emissions development strategy									
GHG or CO_2 emissions reduction target									
Energy efficiency/Conservation target		○ (red)							
Power and water									
Electricity sector conservation target		○ (red)		● (blue)	● (red)	● (blue)			
Electricity sector peak demand reduction target		○ (red)		● (red)		○ (red)			
Renewables deployment target		● (red)		● (red)	● (red)		● (red)	○ (red)	● (red)
Nuclear introduction target		● (red)	● (red)	● (red)	○ (blue)				
Water intensity/Conservation target			○ (red)						
Transport									
Transport sector energy conservation target									
Vehicles efficiency standards									
Appliance and infrastructure									
Energy efficient labelling		● (blue)	○ (red)	● (blue)	● (blue)				
Appliance standards		● (blue)	● (blue)	● (blue)	● (blue)		● (blue)	● (blue)	● (blue)
Mandatory efficiency codes for new builds	○ (red)	● (red)		● (red)	○ (red)		● (red)	● (red)	
National retrofitting targets									
Industry intensity/Efficiency targets									
Oil and gas sector									
Efficiency/Conservation target		● (blue)							
Flaring reduction target				● (blue)		● (blue)	● (blue)	● (blue)	
Other sectoral efficiency/Conservation targets									

● (red) Target or mandatory standard announced at official national level

○ (red) Target or standard aspirational or under proposal

● (blue) Partial/Sector specific (in the case of Oil & Gas Sector = national oil company target)

○ (blue) Imported from Abu Dhabi

Lahn and Preston (2013) Targets to Promote Energy Savings in the Gulf Cooperation Council States.

RECOMMENDATIONS

As we have reviewed in this chapter, energy efficiency policies are in many cases justified because the social and financial benefits of efficiency are not being adequately captured. This situation can arise because of market distortions or other non-market (behavioral) obstacles. The large amount of experience with energy efficiency policy worldwide provides some lessons that can potentially be applied to the situation in Qatar and the GCC. This section will provide an overview of those options by policy area, and will also discuss some sectoral and technology options that could be useful.

Policy Approaches

Policy approaches for energy efficiency fall into three areas:

1. **Information and communication measures** focus on providing more transparent information to consumers and the private sector to encourage better decision-making. Such measures can include programs for labeling, either organized by governments or in public-private partnerships. They can also include public awareness and information campaigns.

2. **Regulations** can be established to encourage minimum levels of efficiency. These regulations are often effective at helping remove the very inefficient technologies from continued use in the economy at low cost. They help push the rate of modernization of technologies slightly forward and have the advantage of cumulative savings over years, as well as the possibility to increase stringency relatively painlessly as technologies improve. Such regulations can include minimum standards, such as for appliances, or building codes for new construction and existing infrastructure.

3. **Market-based instruments** are designed to correct or partially correct distorted price signals in the market, a goal that almost all economists would agree is beneficial to the overall economy and social well-being. Several policies could be said to contribute to this effort. A first step could be harmonizing the prices that consumers and industry pay for energy with the costs of the energy itself. This goal fits with the overall global move toward reducing fossil fuel subsidies that was discussed earlier. A second policy area is to incorporate market externalities into the cost of the energy. This can be done, for example, via a carbon tax or cap-and-trade type system that places a price on the externality.

Given these options, we review some possibilities for efficiency measures in the GCC region and Qatar. Not all policy options may be practical in all countries, but given the unique situation of this region there seem to be several promising areas for improvement.[165]

Efficiency Measures

1. Lower-energy buildings

Countries in the GCC region are building out their housing and commercial space very rapidly, and these buildings could turn into long-term heavy users of energy, particularly for space cooling. Moreover, the resulting savings would be shared not only by industry but also by individual citizens and residents: The share of the residential sector in total electricity consumption exceeds 50 percent in Kuwait, Saudi Arabia and Bahrain, and is about 40 percent in the UAE. This provides a huge opportunity to improve energy efficiency in the construction and management of buildings, for example, via:

- Construction codes or standards for new buildings.

- Building retrofits for improved efficiency.

- Incorporation of lower-energy passive measures such as natural ventilation, night ventilation, evaporative cooling, insulation, and solar control or shading; and active measures such as mechanical ventilation.

- Designing new urban and industrial clusters to minimize energy waste.

A necessary component of this transition toward efficient building stocks is to encourage the private sector to be able to make informed decisions about best practices. Rating systems and performance requirements for efficient building materials and accreditations programs such as LEED in the United States and BREEAM in the U.K. are a helpful component of this transition. In the GCC, the Qatar Sustainability Assessment System (QSAS) created by the BARWA and Qatari Diar Research Institute provides a template for region-specific building-sustainability programs. The QSAS program, which draws on lessons from a range of international frameworks for rating building sustainability and efficiency, offers an accreditation system for buildings that meet a prescribed set of criteria as well as training schemes for professionals in the construction sector. In 2011 portions of the QSAS criteria were incorporated into regulations by the State of Qatar. Abu Dhabi has also launched an initiative for building efficiency through Estidama, its sustainability program. The Estidama Pearl Rating System is a five-point ("pearl") system modeled on LEED system. According to an executive order, all new buildings in Abu Dhabi must meet the minimum "1-pearl" rating from September 2010; all government buildings must meet the "2-pearl" rating. Such programs could be officially incorporated in all GCC member states, and those countries that have already implemented them could investigate the possibility of requiring more broad based or ambitious efficiency targets for future projects.

2. Efficient appliances and industrial equipment

Improving efficiency for appliances, equipment and other technological devices can be supported by a combination of mandated minimum efficiency standards and voluntary labeling for "quality" products that satisfy certain criteria for excellent performance. Goals could be benchmarked domestically or relative to regional or international levels. Rating and labeling programs that provide information to the consumer at the point of purchase about the energy usage profiles and long-term energy costs of competing products are other means of improving efficiency. GCC countries have a number of nascent initiatives that can provide the basis for increased adoption of standards in both the building and appliance sectors. The Saudi Arabian Standards Organization (SASO), for example, oversees the implementation and standards of the national energy efficiency appliance labeling program, as well as mandates for appliance efficiency standards. Also, the UAE's Emirates Authority for Standardization and Metrology (ESMA) has launched an efficiency rating system for air conditioners: Systems are rated according to a star system (with five stars being the most efficient), and those that do not meet the minimum requirement are not allowed into the country. The system has been expanded to refrigerators and freezers in 2012 and to washing machines in 2013. The application of such systems by other countries in the GCC would be a major step toward increasing overall energy efficiency.

3. Energy efficiency as part of a broader clean energy R&D program

Many of the countries in the GCC have a stated aim to diversify their economies away from a reliance on hydrocarbon and petrochemical production through the establishment of educational centers and knowledge-based industries. Existing GCC research establishments (such as the Qatar Science & Technology

Park or Masdar in the UAE as well as the many technical departments in regional universities) have the opportunity to conduct scientific research into energy applications and systems specific to regional conditions—these include catalysts, lubricants, solar panels, hydrogen storage and optimal design of building "envelopes." GCC countries have the potential to serve as a development and demonstration base for efficiency technologies developed both inside and outside the region. There is also an encouraging precedent for public-private partnerships on R&D in Qatar, where Chevron and the Qatar Science & Technology Park have partnered to create the Center for Sustainable Energy Efficiency. The center will focus its research on lighting, cooling and solar technologies adapted for use in the climate of the Middle East. The center has the potential to serve as a venue for further public-private partnerships in the transfer of efficiency best practice within Qatar and as a model for other countries in the region looking to harness the expertise of their private-sector investors.

4. Energy prices

As discussed earlier, economic theory suggests that energy efficiency in the GCC could be significantly improved through a policy of greater market-based pricing and reduced subsidization of energy. In parallel with this is the possibility of a longer-term shift to a tax on emissions, which would provide additional incentives for investments in efficient technologies. Despite the well-known political challenges associated with pricing reform, there are means of enacting incremental pricing reform that are likely to have less of a disruptive impact than a wholesale move to market pricing. These include:

- A phased adoption of increased end-user pricing.
- "Recycling" the revenues from any price increase to improve efficiency of use.
- Differentiated pricing across different consumer groups.
- A mechanism for compensating the most economically vulnerable.

Given the nexus between energy and water use in the GCC, any pricing reform policy for electricity must also take into consideration water supplies and the wide-scale reliance on desalination plants. Before any implementation of large-scale pricing reform, countries of the GCC could consider conducting research into the consequences of a change in the pricing structure of energy, including the effects of a phase out of subsidies and other adjustments toward a more market-based approach.

5. Public-private partnerships in the energy industry

The GCC energy sector is unusually active and globalized, and there are significant opportunities for collaboration between private (international) companies, industry and government in the interests of increased efficiency. Much of the region's energy consumption occurs in the production and processing of hydrocarbons and other carbon-intensive industrial applications. Even without explicit requirements, the financial incentives to save energy are sometimes large: For example, the opportunity costs of wasting energy assets that could otherwise be sold have prompted many of the multinational companies in these industries to implement efficiency measurement and management processes. An example is ExxonMobil, a major joint-venture investor in the GCC, which had developed a Global Energy Management System (GEMS), a program comprising over 200 best practices and performance measures for process units, major equipment, and utility systems in the petrochemicals and petroleum refining operations. Other oil majors present in the GCC have similar institutionalized efficiency programs. Total, also a major investor in the GCC, has a stated goal to improve the efficiency of its exploration and production and petrochemicals production by 2 percent per year over the period of 2007-2012. In 2008, the company published an Energy Performance Management Guide, aimed at getting its staff to deploy more efficient technologies and management practices. While many of the technical directives and guidelines used by energy companies may be specific to the hydrocarbon production sector, some of the efficiency management systems, data collection techniques and analysis tools may also be applicable to other sectors of the economy—such as power generation—that are currently under state management.

6. New government institutions to oversee efficiency

GCC countries could consider establishing energy efficiency authorities under their existing government energy agencies. Such institutions would be under the control of each government in the region and would have responsibility for managing domestic efficiency-related projects, promoting public-private partnerships and building capacity through the training of technicians and educators. They would also be responsible for coordinating with each other on trans-GCC partnerships. If desired, the role of the efficiency authority could also include responsibility for monitoring and analysis of water usage, including examination of the distribution and desalination systems. There is some foundation for such energy authorities in the region. Saudi Arabia's National Energy Efficiency Program (NEEP), for example, studies the possibility of implementation of energy efficiency measures in Saudi Arabia, and has set targets for reducing the country's energy intensity of 2030. Looking more broadly, India has implemented a successful Bureau of Energy Efficiency that could also serve as a model.

7. Utility-driven and utility-led efficiency programs

Because of their closer contact with consumers, utilities are in a potentially useful position with respect to encouraging residential and commercial energy efficiency. Moreover, energy efficiency is an important utility system resource that also reduces greenhouse gas emissions, achieves savings for customers and generates jobs. Utilities in the GCC could develop programs to encourage upgrades to more efficient appliances, to do energy audits on buildings, or to encourage peak load reductions through technological or behavioral incentives. Moreover, smart grids hold promise to enable improvements in energy efficiency within the utility sector through both gathering information on use and helping to manage demand and load. However, to harness the full efficiency and environmental benefits of smart grids would require careful program design and implementation, as well as targeted capital investment. In the U.S., for example, utilities are by far the largest driver of large-scale electricity efficiency programs, with customer-funded electric efficiency programs available in 44 states. Their budgets totaled over $6.8 billion in 2011.[166]

8. New energy management technologies

A final, cross-cutting approach to energy efficiency in the GCC region is to look at opportunities over all sectors to deploy new and more intelligent technologies to achieve energy services with less waste. Such information and communication technology (ICT)-based innovations—including ICT infrastructure and equipment, ICT-enabled buildings and construction, ICT-enabled transport, and ICT-enabled carbon/energy management and reporting—can deliver great energy savings. For instance, Mumbai's real-time, adaptive traffic control systems at 253 crossings, supervised by a central traffic management control center, resulted in a 12 percent reduction in average traffic time in the city, along with an 85 percent reduction in energy usage from the city's traffic lights.[167] A computerized building management system (BMS) that manages and operates various pieces of equipment (usually air conditioning, heating, cooling, ventilation, lighting, maintenance management, security, access and fire systems, etc.) can save 10-40 percent of energy compared with the same building without such a system.[168]

ICT is also leading the evolution of energy infrastructure, where the nature of energy supply and demand is increasingly dynamic and distributed. For example, the number of plug-in electric vehicles has reached 120,000 units worldwide in 2012, and global electric vehicle sales are expected to hit 3.8 million annually by 2020.[169] Utilities are looking toward demand response technologies to shift consumption to lower-cost periods, and they need to be able to respond quickly to demand and supply, which is generated by distributed solar and wind energy, coming on and off the grid. In addition, smart grid and smart networks are generating huge volumes of data. A distribution company with 2 million meters, collecting 15-minute interval data four times a day, processes 35 GB of data every day.[170] Smart meter installation is expected to reach 602.7 million people worldwide by 2016.[171] Cities can leverage the maturing cloud computing and data management technologies that can harness large volumes of real-time data from diverse public and private sources, in order to monitor, measure, analyze, report on and control energy generation, distribution and use on a massive scale.

CHAPTER 4: SOLAR AND OTHER ALTERNATIVE ENERGY

INTRODUCTION

This chapter provides an assessment of the need for alternative energies given global energy demand and efforts to reduce greenhouse gas emissions at the international level. Also discussed are benefits of alternative energy sources, an overview of the types of alternative energy technologies that could be relevant for Qatar and the Gulf Cooperation Council region, and international initiatives, financing and policies for alternative energy. Qatar and the other GCC countries are examined in terms of the potential advantages and challenges to introducing alternative energy, as well as an overview of the existing initiatives and efforts to introduce these technologies in the region. The chapter concludes by outlining several policy options that could help encourage wider development of an alternative energy economy in the GCC.

ALTERNATIVE ENERGY IN A GLOBAL CONTEXT

GCC Energy Demand

Overall economic activity is expected to grow rapidly in the GCC region in coming decades. This domestic economic growth will likely cause many GCC countries to experience increases in the fraction of energy that is consumed domestically, which, of course, renders it unavailable for export. Expectations for rising living standards and increasing dependence on energy-intensive desalination compound the energy challenges. Demand for electricity, which is typically generated by domestic gas, is already outstripping supply in some GCC countries and is expected to rise by 7 to 8 percent per year on average for the coming decade.[172]

In addition, increasing use of fossil fuel energy presents potential hazards to the regional and global environment. Because of their current industrial structures and consumption patterns, Qatar, the United Arab Emirates (UAE), Kuwait and Bahrain have some of the highest per capita CO_2 emission rates in the world. At the same time, many world regions are investing in alternative fuels and energy efficiency, and are developing previously untapped resources, especially shale gas. This increase in production will likely enhance the competition in energy markets for GCC member states.

Benefits of Alternative Energy Sources

Alternative energy offers some benefits when compared with conventional energy sources. For example:

- Alternative sources are often cleaner than fossil fuel combustion, and can improve public health and the local environment by reducing regional air pollutants.
- Some alternative sources such as wind and solar power do not require water for their operation and therefore do not pollute or strain water resources.
- Renewable sources of energy can have important climate change benefits: Greenhouse gas (GHG) emissions throughout renewable energy's life cycle, including manufacturing, installation, operation and maintenance, and dismantling and decommissioning are minimal.[173]
- Renewable energy contributes to economic diversification and job creation in manufacturing, installation, maintenance and other dimensions of the supply chain.
- Renewable power utilizes inexhaustible natural resources that can lead to reduced consumption of

fossil fuels for countries with abundant domestic sources of such fuels. This allows additional exports of oil and gas that are often more valuable on world markets than in domestic markets.

Alternative Energy Technologies in the GCC

While there are many types of alternative energy being developed globally, the GCC countries have some geographic and economic characteristics that offer opportunities for development of several technologies:

- **Solar energy:** Based on annual insolation (aggregated sunny hours adjusted for solar intensity), the Gulf region has some of the highest solar potential in the world. The region's annual average global solar radiation (GSR, available to photovoltaic cells) is estimated at about 6 kWh/m^2 per day. Estimates of the direct normal irradiance available to solar concentrating technology are around 4.5 kWh/m^2 per day. These figures suggest that a land area of approximately 1,000 km^2 (0.2 percent of the GCC) covered with photovoltaics (PVs) at 20 percent efficiency could produce 438 terawatt-hours (TWh) every year—about the entire electricity demand of the region.[174] Peak energy demand in GCC is during the daytime in August and September, when air conditioning use is the highest, coinciding with the highest GSR levels over the year.

- **Wind energy:** This alternative source is also available in the GCC countries, particularly in the coastal and gulf areas. Countries with more than 1,400 hours of wind per year are considered to have economically viable wind energy. Saudi Arabia has the most recorded hours of full wind load per year among GCC countries, at 1,789 hours.[175] Data from the Saudi Arabian Presidency of Meteorology and Environment have shown considerable wind potential in the Arabian Gulf in November, December, January and February, with wind speed averages at 5.39 m/s, 7.27 m/s, 7.35 m/s and 6.26 m/s.[176] However, better data and mapping for offshore wind resources are needed.

- **Biofuels:** The Gulf region also has potential for algae biofuels. Its large non-arable lands, extensive coastline and high annual solar irradiance create ideal conditions for the growth of algae. Its existing physical infrastructure and human capital in areas such as oil refineries, power plants, desalination plants, and sewage and wastewater treatment plants provide the capacity for CO_2 capture, salt reuse and water treatment in the algae biofuel industry. Furthermore, the International Energy Agency (IEA) estimates that biofuels will make up about 30 percent of aviation fuel supplies by 2050.[177] As the GCC establishes itself as a world-class aviation hub and tourist destination, biofuels, when done right, can bring significant economic benefits and emission reductions for the region's airlines.

In the Gulf region, natural resources vary over specific geographical locations, which means that not all technologies will be appropriate for all places. Moreover, the policies and industrial structure in individual countries vary, which means that the existing barriers and appropriate policy options for each country might be different across those countries as well. Nevertheless, the region as a whole, much like other world regions, exhibits a few general characteristics that are currently hindering more rapid deployment of renewable energy. A few examples include price distortion from fossil fuel subsidies, market failure to value the public goods nature of renewables, inadequate information, high transaction costs, and outstanding barriers to international trade and investment. Because these problems have been an issue across the globe, other countries have tried a diverse set of policies to promote renewable energy. Lessons from those experiences can be applied to the specific context of the GCC.

In this chapter we will focus on policies that address several particular barriers. For example, high initial capital requirements can present a barrier to renewable energy deployment, but this is an area that many countries within the GCC can address through government action or the catalyzing of private sources of finance. In addition to common challenges in renewable energy deployment, GCC countries also face some specific policy and technological issues in developing alternative energy in the region, including the effect of high temperature and dust on solar energy, the lack of detailed studies of wind characteristics in the region, and the lack of understanding of the costs and benefits of biofuels being developed recently. Such areas are also manageable with some direction from governments and coordination with the many new energy research centers in the region.

INTERNATIONAL INITIATIVES

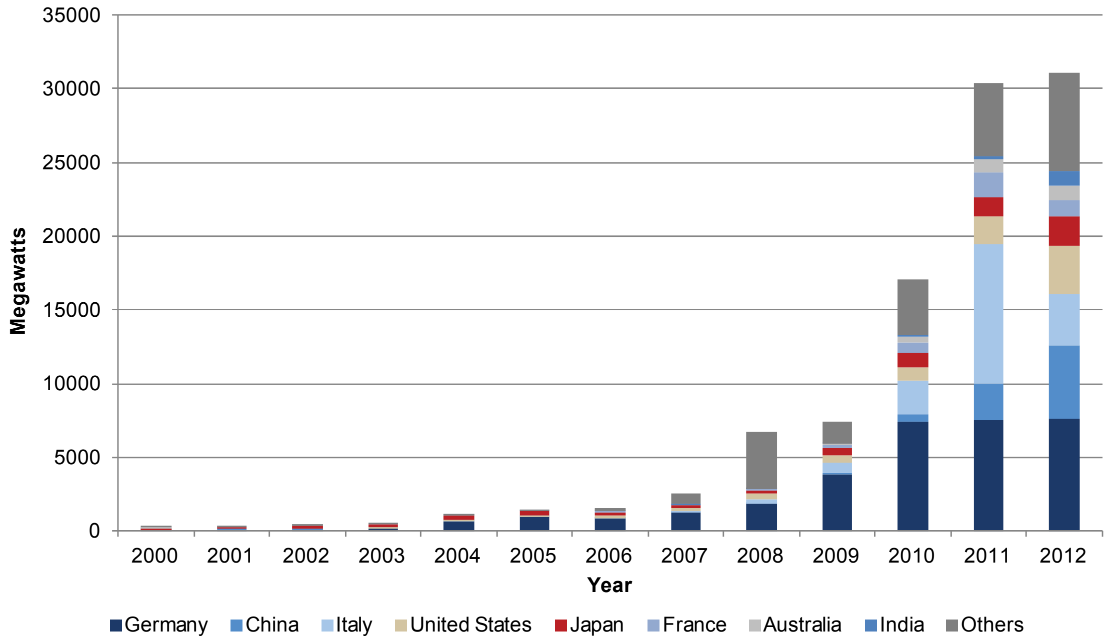
International Solar and Alternative Energy Initiatives

Renewable energy is now the fastest-growing power generation sector globally. From 2000 to 2012, cumulative global installed renewable energy capacity has grown by 96.5 percent, from 748 GW to 1,470 GW.[178] In absolute terms, global renewable generation in 2012 reached 4,860 TWh, more than the estimated total electricity consumption of China, and represents about 21.7 percent of global electricity.[179] In just five years, solar PV capacity increased from below 10 GW in 2007 to over 100 GW in 2012. In addition, the amount of annual installation has increased rapidly: In 2012 alone, global capacity of wind (onshore and offshore) rose by approximately 45 GW (an increase of 19 percent) from 2011, and solar PV by an estimated 30 GW (an increase of 42 percent).[180] The amount of annual consumption of renewable energy has also increased sharply: In 2012, wind power consumption increased by 18 percent to 521 TWh, and solar power increased by 58 percent from 2011, to 93 TWh.[181] The IEA estimates that renewables will make up almost a quarter of the global energy mix by 2018. The share of non-hydro renewable sources such as solar, wind, geothermal and biomass will double, reaching 8 percent by 2018, up from 4 percent in 2011 and just 2 percent in 2006.[182] Another recent report by the International Renewable Energy Agency (IRENA), projects renewable energy trends to 2030 and estimates that, by doubling the rate of energy efficiency improvements and providing universal access to modern energy services via renewables, the renewable energy share could rise to as much as 36 percent by 2030.[183]

By the end of 2012, the countries with the greatest renewable energy capacity were China, the United States, Brazil, Canada and Germany; the top countries for non-hydro renewable energy capacity were China, the United States, Germany, Spain, Italy and India (see Figures 4 and 5). Notably, the BRICS nations accounted for 36 percent of total global renewable capacity and almost 27 percent of non-hydro renewable capacity.[184] This rapid increase in renewable energy was spurred by falling prices and strong policy support from governments in China, Germany, Japan, Spain and others. The price of crystalline silicon photovoltaic cells dropped from $76.67/watt in 1977 to an estimated $0.74/watt in 2013.[185] This decrease has recently accelerated with scale economies—even in the past two years, prices have dropped by 60 percent.[186] In the EU, some mid- and small-sized solar projects are being developed without subsidies. In southern Italy, where net metering and self-consumption are being incorporated, solar projects are delivering electricity at $1.20/watt. Solar power in India comes at $1.52/watt, and Australia's residential solar power, before subsidies, is at $1.90/watt.[187]

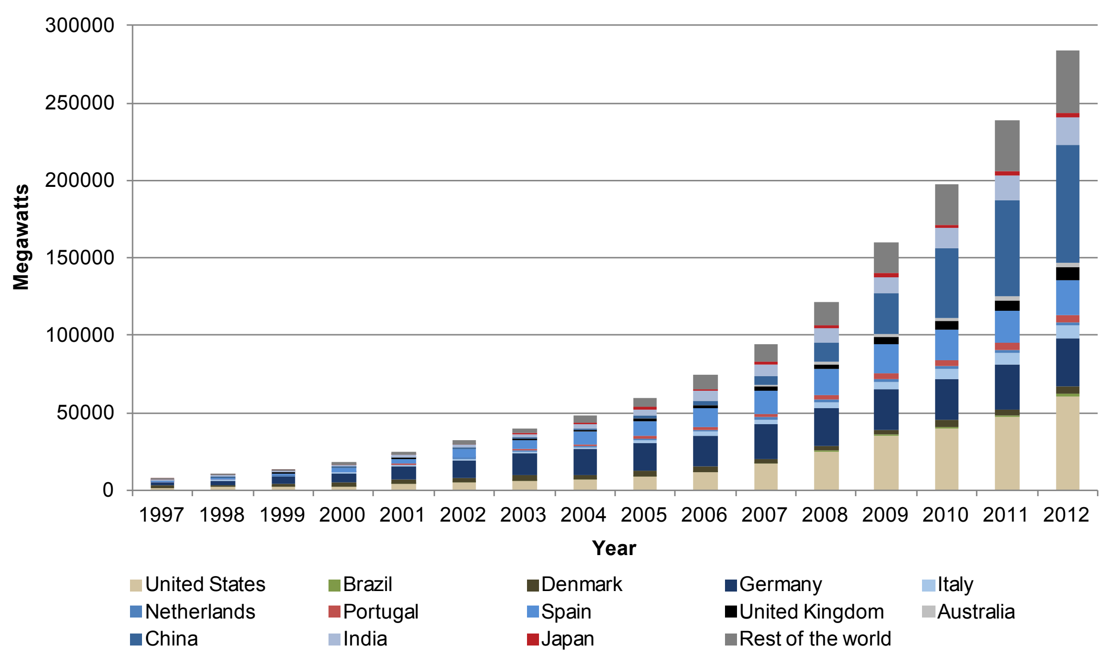
Wind energy prices have also been decreasing. The levelized cost of energy (LCoE) for wind is estimated to be at an all-time low in 2012-2013. Relative to their 2008 peak price, wind turbine prices have fallen by approximately 25 percent in western markets and by 35 percent in China by 2012.[188] According to a joint study by NREL and LBNL, the best wind sites in the

Figure 4: Installed solar photovoltaics capacity in selected countries and the world, 2000-2012 (MW)



Earth Policy Institute (2013) Data center; 2000-2012 data for China and the world and 2011-2012 data for all other countries from European Photovoltaic Industry Association (2013) Global Market Outlook for Photovoltaics 2013-2017; 2000-2006 data for countries excluding China from IEA Photovoltaic Power Systems Programme (2012) Trends in Photovoltaic Applications: Survey Report of Selected IEA Countries between 1992 and 2011; 2007-2010 data for countries excluding China from EPIA (2012) Global Market Outlook for Photovoltaics Until 2016.

Figure 5: Cumulative installed wind capacity, 1997-2012 (MW)



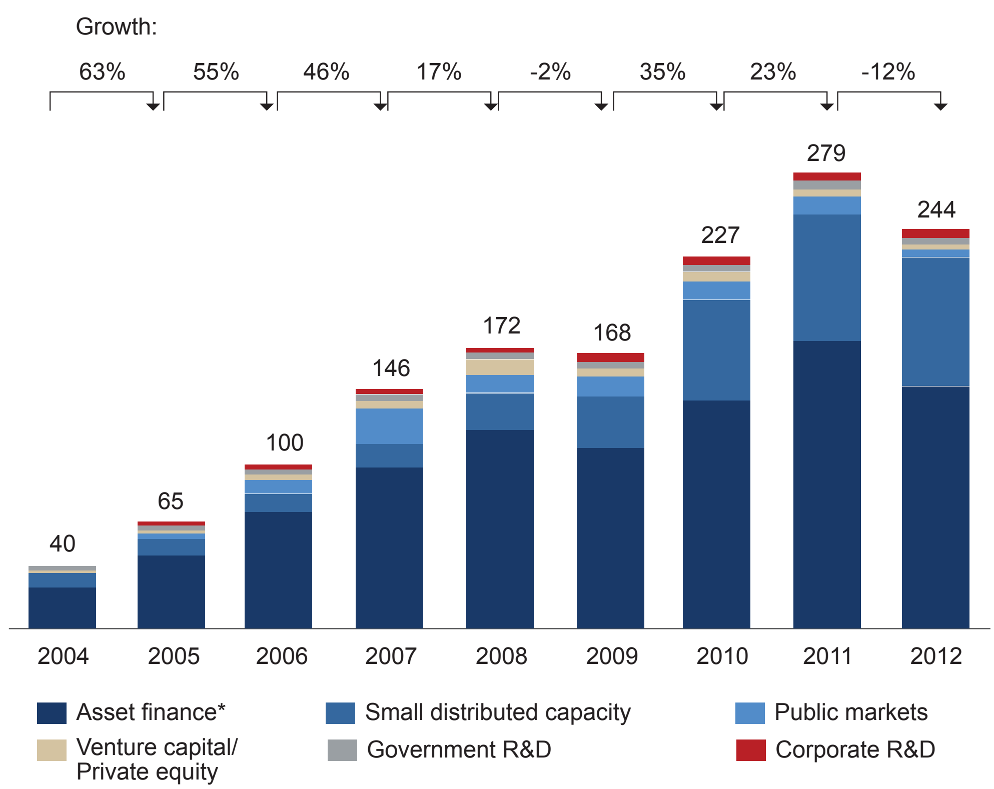
BP (2013) Statistical Review of World Energy 2013.

U.S. can support LCoE at 3.3 cents/kWh, and the lowest wind speed sites, 6.5 cents/kWh.[189] In Brazil, average onshore wind prices fell to 4.2 cents/kWh in December 2012, 12 percent lower than the prior year.[190] These numbers indicate that onshore wind is competitive with natural gas power especially in areas of higher prevailing energy prices. The LCoE of current offshore wind projects in Europe is 17.1 cents/kWh, and those projects entering into service in the U.S. in 2018 are projected to average 19.34 cents/kWh.[191] Roland Berger estimates that offshore wind LCoE will drop to 11.88 cents/kWh by 2020.[192]

Global Investment in Alternative Energy

Global investment in new renewable energy projects, excluding hydropower, was $244 billion in 2012. This is 11 percent lower than the record $279 billion in 2011, reflecting the policy uncertainty in some key countries (Figure 6). For instance, the potential expiration of a production tax credit for wind in U.S. at the end of 2012 slowed down investment in wind capacity. Similar uncertainty surrounding the expired tax- and generation-based financial incentives in India stalled wind investment there.

Figure 6: Global investment in renewable energy by asset class (billions of dollars)



Frankfurt School-UNEP Centre, BNEF (2013) Global Trends in Renewable Energy Investment 2013.

Alternative Energy Policies

Worldwide, a number of policies have been enacted to promote renewable energy. As of early 2013, 71 countries and 28 states/provinces had adopted some form of feed-in tariff (FIT), including Jordan, Malaysia, Rwanda and Ukraine, which introduced FIT systems in 2012. Twenty-two countries and 54 states/provinces in the U.S., Canada and India have renewable portfolio standards (RPS) or quotas for renewable power generation. Net metering policies are in place in 37 countries, including Canada (in 8 provinces) and the U.S. (in 43 states, Washington, D.C. and four territories). A host of fiscal incentives exist to help overcome the financial barriers to deploying renewables. In the U.S., the production tax credit for wind was extended to 2013 and revised to expand eligibility. Cameroon removed the value-added tax on all renewable energy products in 2012. Table 6 provides highlights of alternative energy policies from some select countries.

In terms of algae-based biofuels, most development is currently being led by developed countries, with the exception of developing countries like China and India, which are funding algae biofuel R&D collaborative projects among universities, research institutions and industries. ExxonMobil and Synthetic Genomics have a $600 million R&D venture committed to algae-based biofuels. In 2008, a consortium of private and public investors, including the Gates Foundation, the Rockefeller Foundation, BP, Chevron, the U.S. Department of Energy, etc., invested over $300 million towards commercialization of this technology.[193]

ALTERNATIVE ENERGY IN THE GCC

Advantages and Challenges in the GCC Region

- **Solar energy:** It is well known that the efficiency of crystalline silicon photovoltaic solar cells decreases linearly with the rise in temperature,[194] an issue that has real consequences for solar production in the GCC. Nevertheless, even though efficiency decreases as temperature increases, this may be compensated for by increasing solar intensity. Therefore, overall power production from PV panels may go up on a hot sunny day because of the abundance of sunlight. In addition, some technologies, such as thin-film panels based on CuInSe2 and CdTe, are able to maintain efficiency at higher temperatures and do not register significant temperature-dependent degradation until around 100°C.[195] Developing and deploying such heat-insensitive technologies could improve overall solar PV economics in the GCC.

  Another issue in the GCC for solar energy is the accumulation of dust on the panels, particularly as water for washing is in short supply. A number of studies reviewed the impact of dust on the performance of photovoltaic panels and a variety of cleaning methods, including cleaning with water, cleaning with surfactant, using specialized coatings and self-cleaning mechanisms.

- **Wind energy:** One major barrier to wind energy deployment in the GCC region has been the lack of data collection for wind characteristics. IRENA and the German Aerospace Center (DLR) recently launched a collaborative graphic information system of global solar and wind resources in January 2014, the Global Atlas for Solar and Wind Energy project, which is an overview of existing initiatives and outcomes.[196]

- **Liquid biofuels:** Microalgae are a potentially promising feedstock for future transport fuels. Algae can be grown almost anywhere, even on sewage or salt water, and do not require fertile land or food crops. They have much faster growth rates than terrestrial crops. The yield of oil from algae is estimated to be 20,000 to 80,000 liters per acre per year. With a minimum input of additional energy to harvest and process, microalgae can be converted to biodiesel, bioethanol, bio-oil, biohydrogen and biomethane. Algal-based biodiesel can be used for cars, trucks and airplanes.[197]

Table 6: Comparison of solar and alternative energy policies in selected countries				
	China	**Germany**	**India**	**South Africa**
National RE targets	15% RE by 2020	35% RE by 2020; 80% by 2050	15% RE by 2020	13% RE by 2020
Solar PV in 2011	Total installed capacity: 3.1 GW; Annual manufacturing capacity: 66.3 GW	Total installed capacity: 24.8 GW; Annual manufacturing capacity: 5.3 GW	Total installed capacity: 0.5 GW; Annual manufacturing capacity: 2.2 GW	Total installed capacity: 30 MW
Wind in 2011	Total installed capacity: 62 GW; Annual manufacturing capacity: 61.3 GW	Total installed capacity: 29 GW; Annual manufacturing capacity: 9.5 GW	Total installed capacity: 16 GW; Annual manufacturing capacity: 4.6 GW	Total installed capacity: 10.1 MW
National policies	Ambitious targets; fixed FITs; tax incentives and subsidies; grid connection requirements; low finance rates	Ambitious targets; comprehensive RE law w/ FITs, tax incentives and provisions for grid interconnection; investment incentive packages; structured innovation policies and programs, including PPP and workforce development. Started phasing out solar FIT by 2018, enacted subsidy for energy storage	Ambitious targets (for solar); FITs; capital subsidies; tax incentives	Ambitious targets; switched from FIT to a bidding program (REIPPP)
Assessment of policies	Policies mainly designed to boost efficiency and domestic economy; has driven exponential manufacturing and lowered cost of RE globally. Recent push for domestic installation of RE, instead of for export.	Stable and comprehensive policy framework has been key driver to building Germany's RE industry.	Key policies linked to National Action Plan for Climate Change, but growth constrained by limitations in infrastructure, access to finance, and policy inconsistences at state and national level.	Lack of coordination at the policymaking level and uncertain regulatory environment hamper RE development.

Notes: GW: gigawatts; RE: renewable energy; FIT: feed-in tariff; PPP: public private partnership; REIPPP: Renewable Energy Independent Power Producer Procurement Programme

WRI (2012) Delivering the Clean Energy Economy: Why Policy Matters; WWF and WRI (2013) Meeting Renewable Energy Targets: Global Lessons from the Road to Implementation; World Wind Energy Association (2013) World Wind Energy Report 2012; Pienaar (2011) Shifting Policies Stall South Africa's Renewable Energy Growth; Maphelele et al. (2013) South Africa Solar Energy Technology Road Map; and Sawhney (2013) Policy Monitor Renewable Energy Policy in India: Addressing Energy Poverty and Climate Mitigation.

Qatar and GCC Region Solar and Alternative Energy Initiatives

GCC member states have been active in investigating solar power opportunities and initiating new projects. The six countries altogether have approved solar projects worth approximately $155 billion, which will generate more than 84 GW of power when complete in 2017. Saudi Arabia and the UAE accounted for most of these solar projects.

Qatar has established an ambitious renewable energy deployment target of 20 percent by 2030. At this stage, state efforts have focused on developing technical capacity in the country via research centers, universities and pilot projects to jump-start market activity. A few highlights include:

- *A planned 200 MW solar project* to be developed by Qatar Solar Technologies, a venture between the private charity Qatar Foundation, Germany's SolarWorld AG and the Qatar Development Bank. This project aims to produce polysilicon, manufacture photovoltaic panels and install the devices. In May, the venture obtained financing for a $1 billion polysilicon plant in Ras Laffan City from Islamic lender Masraf Al Rayan. The facility will initially produce 8,000 metric tons of polysilicon a year and enough of the raw material for 6.5 GW in panels when at full capacity.

- *A 200 MW mixed renewable project announced at COP18.* The president of the Qatar General Electric and Water Corporation (KAHRAMAA) and Qatar's energy minister announced this project at the international climate conference in Doha in 2012. Phase 1 of the project would involve 5 to 10 MW of pilot plants and would cost around $30 million. Phase 2 will assess the results of the initial projects in attracting private sector involvement for an eventual 150 to 200 MW scheme, developed over the following years, up to 2020.

- *A new solar test facility located in the Qatar Science & Technology Park.* Chevron and GreenGulf, a Qatar renewable energy company, invested $10 million to advance solar energy, solar air conditioning and energy efficiency.

- *A program to develop biofuels.* Qatar Airways has announced plans to partner with Airbus, the Qatar Science & Technology Park and Qatar Petroleum to develop biofuels for use in air transportation.

Saudi Arabia plans to double its installed electricity capacity by building 54 GW of renewable energy (as well as 17.6 GW of nuclear power) by 2032, of which 41 GW (30 percent of total electricity) will be solar power; 25,000 MW will be from concentrating solar power plants; and 16,000 MW will be from solar photovoltaics. This ambitious plan requires an investment of $109 billion. Bloomberg New Energy Finance estimates that, by building solar PV plants and selling the displaced oil on the international market, the state can generate an internal rate of return of approximately 12 percent.[198] Other notable projects include:

- *Saudi Aramco's expansion of its 3.5 MW KAPSARC solar park in Riyadh*, currently the biggest ground-mounted photovoltaic plant in the country, to 5.3 MW. Construction on phase II of the project began in June 2013.

- *Saudi Electricity Company's 500 kW pilot solar plant* on the Farasan Islands came online in 2011 and is Saudi Arabia's first solar power plant.

- *Phase I of the King Abdullah Initiative for Solar Water Desalination* is expected to be operational by the end of 2013. The first phase of the project started in 2010 and resulted in two solar plants being constructed in Al-Khafji and Al-Oyainah, providing a total of 10 MW of solar-generated energy for the desalination plant that would have a capacity of producing 30,000 m^3 of drinking water per day to meet the needs of the 100,000 Al-Khafji residents.

The United Arab Emirates currently has 20 megawatts of solar energy capacity, including 36 solar installations that generate, in total, 10 MW of electricity and hot water, as well as the first grid-connected 10 MW solar power plant in Masdar City. By the end of 2013, new projects underway are expected to bring the total to 140 MW. It is expect that at least 800 additional MW of solar power will come on stream by 2020, and another 900 MW before 2030.[199]

- *Projects at the city level*, for example, Abu Dhabi announced a target of 7 percent renewable energy generation capacity by 2020 (1,500 MW) in 2009. The $3.2 billion Mohammed bin Rashid Al Maktoum Solar Park in Dubai covers 48 km^2, and aims to generate 1 GW from PV and concentrating solar power installations by 2030. The first part of the park, a PV plant with a capacity of 13 MW, is expected to finish construction by the end of this year. The plant is self-funded by members of the supreme council of energy.

- *Bilateral initiatives*, e.g., Masdar announced that it will invest up to Arab Emirates dirham (AED) 6 billion ($1.6 billion) in alternative energy projects alongside the U.K.'s Green Investment Bank. It is currently evaluating solar thermal technology at its Masdar City project and has installed a field of hybrid solar photovoltaic-thermal system solar thermal panels as a pilot project. Abu Dhabi is also investing in alternative energy abroad, such as the London Array and in Gemasolar. In terms of biofuels, the UAE-based Etihad Airlines is working with Boeing (U.K.) to research whether plants that can be grown in seawater mangroves around Abu Dhabi could be used as biofuel feedstock.

- *Financial incentives*, for example, Abu Dhabi has launched a government sponsored financial incentive program in the form of a solar rooftop plan designed to make the use of solar photovoltaic technology on rooftops more affordable to Abu Dhabi building owners. This project is led by Masdar and the Abu Dhabi electric utility ADWEA. The program aims at achieving 500 MW PV on rooftops within 20 years.

Kuwait has also announced national renewable energy deployment targets in late 2012, aiming to achieve 1 percent by 2020 and 15 percent by 2030. In June 2013, Kuwait invited bids for its first solar energy project, to be built in Shagaya. The first phase of the project will have a capacity of 70 MW by 2016, of which 50 MW will come from solar thermal sources and 10 MW each from photovoltaic and wind sources. The second and third phases will have a capacity of 930 MW and 1,000 MW, respectively, when the project is completed in 2030.

In Bahrain the development of renewable energy is at an early stage. The country is constructing a 5 MW solar and wind power station (3 MW from solar and 2 MW from wind), which is due to be implemented in the next five years. The project is a collaboration involving the National Oil and Gas Authority, Bahrain Petroleum Company (Bapco), the Electricity and Water Authority and the University of Bahrain. According to Bapco, nearly 21,000 solar panels, covering an estimated 34,000 m^2, have been installed by April 2013. Another 5 MW solar PV project was launched in 2012 and is a joint venture between BAPCO, NOGA and two U.S.-based firms, Caspian Energy Holdings and Petra Solar. With total investment set to reach $26 million, the solar project is a first for BAPCO and includes involvement from several government bodies. Bapco opened HRH Princess Sabeeka Park in February 2010, which includes a model scientific laboratory for renewable energy.

In Oman, Sultan Qaboos bin Said's "Vision 2020" decree set the target of producing 10 percent of its total electricity from renewable energy sources by 2020. A ministerial committee has been established to oversee and coordinate efforts and is chaired by the Ministry of National Economy. Oman is undertaking the development of several projects, including:

- Plans to initiate tenders for two solar projects, each of between 100 MW and 200 MW, in the towns of Adam and Manah.

- In mid-January 2012, Terra Nex Financial Engineering AG and the German Middle East Best Select (MEBS) Group of Funds announced plans to invest $2 billion in PV solar power in Oman, including a 400 MW solar power plant, and silicon production, solar panel and aluminum frame manufacturing. The manufacturing arm of this project is expected to produce 120 MW of solar panels a year initially and create over 2,000 direct and indirect jobs.

- In July 2011, Petroleum Development Oman awarded the first solar thermal enhanced oil recovery project to GlassPoint Solar. The project will use a 7 MW solar array to produce 11 tons/hour of high pressure steam that will be used to extract 33,000 barrels of oil. It will also provide 24-hour heating.

- The potential of wind energy production has been outlined in Oman Power and Water Procurement Company's seven-year outlook for power generation and desalinated water supply in Oman for the time period 2012-2018 and two wind energy-based pilots, each of 3 MW capacity, are planned to be located at Masirah and Thumrait.

RECOMMENDATIONS

A strategy to enhance the development and deployment of alternative energy technologies in the region needs to establish technical expertise, ensure robust technologies are available at reasonable cost, and create the market and policy conditions to encourage their uptake by the private sector. Such a program could draw from any or all of the following six recommendations:

Resource Assessment and Data Collection

The ultimate financial return from many renewable energy technologies depends heavily on the quality of the resource—such as wind or solar. Until very recently, little was known about these resources in the GCC because most mapping was done through remote sensing (satellite) data collection and very broad extrapolations from ground measurements. A high priority is therefore to continue and expand progress toward resource assessment in the GCC. Recently, resource assessment and mapping has gained significance as part of the GCC region's rapid ongoing adoption of renewable energy sources such as solar and wind, to complement fossil fuels. In 2012 the UAE Directorate of Energy and Climate Change, Dubai Supreme Council of Energy, and Environment Agency of Abu Dhabi launched the Research Center for Renewable Energy Mapping and Assessment at Masdar Institute. Additionally, a workshop was held in July 2012 at the Masdar Institute to identify collaboration opportunities in resource-mapping activities,[200] and in 2013 the Masdar Institute developed the UAE solar and wind energy resources maps. The UAE Solar Atlas was subsequently made publicly available to the international community through the Global Atlas online portal developed by IRENA.[201] Such programs, as part of a systematic data collection strategy, can greatly enhance siting and assessment of the appropriateness of these technologies. As such, they should retain a high priority for the coming few years as a precursor to broader renewable deployment.

Renewable Requirements

Minimum requirements for the share of renewables can ensure certain milestones are met for renewable energy deployment. In such cases, there has been much discussion of the "feed-in tariffs" that were used frequently in Europe. However, such tariffs may not be effective in many GCC countries because of the more centralized nature of their utilities, and the lack of tax systems rendering feed-in tariffs untouchable.[202] One possible alternative approach is the renewable portfolio standard (RPS), which mandates that a certain fraction of utility energy should come from a basket of specific technologies, such as wind and solar, or renewables in general. There is some precedent for RPS implementation in the region, as Abu Dhabi has committed to provide 7 percent of its total power generation capacity from renewable sources by 2020.

Region-Specific Technological Research

The region has recently seen the establishment of many research centers and university programs on energy, which can provide the basis for building out effective research programs. But the research areas should be selected carefully in niche areas for which the region can provide some comparative advantage. Moreover, GCC member countries are in the unusual position of being able to support demonstration projects in a few selected technological areas. Appropriate niche applications could include, for example, a new line of technology or a regionally specific application. As discussed earlier, algal biofuels and dust-preventive or dust-resilient technologies represent two potential specialization areas.

Energy-Pricing Reform

Worldwide, fossil fuel subsidies have led to investments that depend on low-cost energy. Undoing those investments may have to be a gradual process, but in the long run the economic costs of continuing subsidies is not sustainable for national accounts or the environment. And while some alternative energy sources can compete with fossil fuels at world market prices, subsidized fossil fuels make the barrier to widespread adoption of alternatives very high. Reforms to pricing could be made incrementally by initially seeking to address two types of subsidies—those paid out either in-kind or as financial support to the private sector, and revenues foregone because of excess domestic demand. The diversion of some of this support to producers of electricity from renewable sources could help those utilities develop a portfolio of low-carbon alternatives. While pricing reform is potentially difficult, planning a gradual transition could be in the long-term interests of macroeconomic health as well as cleaner energy use.

Public-Private Partnerships

Public-private partnerships could help utilities, governments and private sector partners in several ways. First, by engaging industrial partners, governments can encourage innovation in areas that suit both government goals and private sector interests. Ideally, those partnerships can evolve into broader innovation ecosystems that draw in research partners and global expertise. Second, partnerships can help signal to investors the likely trajectory of energy policy and government priorities in the coming decade.

Alternative Finance

One potentially attractive way of financing renewable energy projects in the Arab countries is through Sukuk. Sukuk are certificates representing undivided shares in ownership of tangible assets, usufruct and particular projects or special investment activities. For Islamic financial institutions and corporations, Sukuk offer considerable advantages in liquidity management, fundraising, securitization and balance sheet management. For investors, Sukuk offer the ability to invest in a Sharia-compliant asset class with high tradability. This approach could address one of the big private sector obstacles to smaller-scale renewables: the upfront high capital investment cost.

CONCLUSION: SYNTHESIS AND RECOMMENDATIONS

There is no doubt that energy choices matter for a country's long-term economic growth, social well-being and environmental health. Although resource variation and history affect the present day energy situation in every country, those factors do not condemn any country to any one path into the future. Throughout the world, countries have been able to affect their long-term energy trajectories through specific and concrete decisions. Policy decisions at the government level can influence the suite of technologies that are profitable and can provide a signal of stability for long-term investment. Decisions within industry and the private sector can influence firms' long-term profitability and guard against price volatility and policy risks. Additionally, energy decisions at the consumer level can have a real impact on household budgets and quality of life.

After decades of strong growth supported by the energy industry, Qatar and other Gulf Cooperation Council (GCC) countries are now in a position to evaluate their possible energy futures. Just as for any country, each GCC state will have different resources and historical factors that have led it to its present-day economic structure and energy system. But most also have the capacity and capital now to choose from a wide set of optional energy futures. The preceding four chapters have reviewed a wide variety of considerations for this choice: a deep examination of the global interest in climate change and in greenhouse gas emissions reduction; an assessment of the state of carbon capture and storage (CCS); energy efficiency; and alternative energy and solar technology. Each of the chapters concludes with a review of specific opportunities in Qatar and other GCC countries and an overview of possible policy options to address market failures and encourage different energy pathways. However, while sectoral policies are essential, energy systems are clearly much more than a collection of sectors, and it therefore makes sense also to review options from a broader perspective. For example, individual policies on appliance efficiency or CCS research may be partly effective in isolation, but more likely to succeed and succeed definitively in the context of a broad national vision. Such a national vision would include goals for the energy pathway as well as a broad-based and diverse set of policies across sectors that act in concert to influence individual decisions and mold expectations about the future. In addition, such national visions are most effective when anchored in clearly articulated and broadly shared national goals such as energy security, social well-being, international leadership, human health and sustainability. Such approaches have been effective in previous examples of major energy transitions undertaken at the national level.

History has shown that cases of successful energy technology development have often required a strong and sustained national priority in conjunction with a natural evolution from existing domestic infrastructure—bioethanol in Brazil, bioenergy in Sweden, wind in Denmark and solar photovoltaics in Japan are just a few examples. If Qatar and the other countries of the GCC wish to pursue similar strategic energy technology development, they will have to assess their place in the innovation and manufacturing value chain. A comprehensive approach to strategic energy-technology choice would require the development of a range of competencies and related human capital in everything from pre-competitive research and development, to the launch of capital-intensive industrial and manufacturing processes, to the management of investments in demonstration projects both regionally and globally. The development of institutions able to support such industries will require close coordination between the public and private sectors. With a strong national vision in place, it is then helpful to examine the areas that offer early and substantial opportunities for reaching the vision. As an organizing principle, such areas can provide focus to sectoral policies and help make concrete any national energy action plans. Across the GCC, several such areas stand out as attractive: technology innovation, industrial efficiency, alternative sources of supply, restructuring the energy market and effective governance.

POLICY PROGRAM 1: TECHNOLOGY INNOVATION

Many of the biggest challenges facing countries today—economic growth in high-value activities with broadly shared benefits, poverty reduction and environmental quality—could be addressed substantially with clean and sustainable technologies that raise productivity and create new markets. Such innovation, which often has broad social benefits, has the potential to unlock solutions to challenges like climate change, energy access, environmental degradation, sanitation and water scarcity. Moreover, embracing new pathways that are more environmentally and socially sustainable need not divert resources from economic productivity, but rather can serve to fuel the engine of economic growth.[203]

The GCC region as a whole presents a few factors that could provide a basis for fostering new, low-carbon technologies. It has a combination of substantial risk capital, existing domestic technical capacity across a number of energy engineering areas, strong global partnerships in energy industries, and a growing set of research and technology development institutions. Using these factors to their full advantage could involve a combination of policies to encourage R&D in the region but also to encourage domestic interest and demand for these technologies. While governments should be careful about excessively supporting individual sectors ("picking winners"), several technological areas could clearly benefit from GCC regional research—CCS, liquid biofuels, building efficiency techniques for extreme climates, and development of more robust solar and wind technologies. Qatar and the GCC region as a whole have substantial resources and R&D capabilities that can be used to address climate change. The country's capacity to develop climate change technologies is a key strength and could create new markets for Qatar both at the regional and international levels as a leader in low-carbon technologies.

R&D Programs for Select Technologies

The region has recently seen the establishment of many research centers and university programs on energy, which can provide the basis for building out effective research programs. But the research areas should be selected carefully in niche areas in which the region has a comparative advantage. Moreover, GCC member countries are in an unusual position of being able to support demonstration projects in a few selected technological areas. Appropriate niche applications could include, for example, a new line of technology or a regionally specific application. These technological areas include:

- *Carbon capture and storage*. In terms of developing CCS technology, Qatar's current efforts on the development of CCS technology are fragmented and initiatives to date have been project oriented. A more focused effort to develop expertise on CCS could make Qatar a leader in the region and contribute to domestic climate change goals. Qatar could consider whether it wants to develop an industrial-scale CCS demonstration plant. This could be done as part of EOR or GTL activities. Qatar could also seek to develop specific CCS technologies that build on domestic experience with gas extraction and using CO_2 for EOR with an eye to the commercialization of these technologies for use in other countries.

- *Efficiency*. Existing GCC research establishments—such as the Qatar Science & Technology Park or Masdar in the United Arab Emirates (UAE), as well as the many technical departments in regional universities—have the opportunity to conduct scientific research into energy applications and systems specific to regional conditions. These applications include catalysts, lubricants, solar panels, hydrogen storage and optimal design of building "envelopes." GCC countries have the potential to serve as development and demonstration bases for efficiency technologies developed both inside and outside the region. There is also encouraging precedent for public-private partnership on R&D in Qatar, where Chevron and the Qatar Science & Technology Park have partnered to create the Center for Sustainable Energy Efficiency. The center will focus its research on lighting, cooling and solar technologies adapted for use in the climate of the Middle East. The center has the potential to serve as a venue for further public-private partnerships in the transfer of efficiency best practice within Qatar and as a model for other countries in the region looking to harness the expertise of their private-sector investors.

- *Alternative energy*. As discussed earlier, algae biofuels and dust-preventive or dust-resilient technologies represent two potential specialization areas. The area with the most promise for Qatar involves the development of solar energy technologies. Qatar is already undertaking R&D initiatives under its national renewable energy deployment target, including a new solar test facility and advances on biofuels.

- *Smart grid and energy management.* A final, cross-cutting approach to energy in the GCC region is to look at opportunities over all sectors to deploy new and more intelligent technologies to achieve superior energy services with less waste. Such information and communication technology (ICT)-based innovations would include ICT infrastructure and equipment, ICT-enabled buildings and construction, ICT-enabled transport, and ICT-enabled carbon/energy management and reporting, which can deliver great energy savings.

R&D Finance

While national policy is the key contextual driver of any innovation ecosystem, international partnerships can help fill the gaps that currently exist by fostering strong innovation ecosystems and increased innovation outputs. Financial contributions by Qatar could help underpin these partnerships while providing the country with access to cutting edge R&D in the U.S. and elsewhere. For instance, the pledge in 2007 by Gulf countries in OPEC of $750 million (including $150 million from Qatar) to a new fund to tackle global warming through research for a clean environment could be model for developing international climate change and clean energy research partnership at a government-to-government level. A national fund for Qatar to support and finance mitigation and adaptation projects as part of its comprehensive climate change policy framework could support domestic climate change and energy goals such as the development of renewable energy projects and climate change technologies. By setting up its own national climate fund, Qatar could attract international finance for domestic investments in clean technology and generate revenues through the taxation of existing resources such as in the oil and gas sector. A carbon price would also support the economic viability of clean energy technologies like CCS. An economy-wide carbon price is the most efficient way of reducing GHG emissions. By equating the marginal cost of abatement with the carbon price, emissions costs are equalized across the economy and this equalization, in turn, would incentivize the development of technologies for reducing CO_2 emissions.

R&D Cooperation

GCC-wide cooperation such as the EU-GCC Clean Energy Network—an instrument for the development of cooperation activities on clean energy policy and technology in the areas of renewable energy sources, energy efficiency, clean natural gas and carbon capture and storage—provides another avenue through which to pursue international cooperation on clean technologies.[204] Qatar should also consider further bilateral cooperation on clean technology, such as partnerships with the Potsdam Institute for Climate Impact Research (PIK), and involve both government ministries and research institutions. This could be modeled on bilateral partnerships such as the U.S.-China Clean energy partnership, which comprises clean technology energy projects between U.S. Department of Energy laboratories and the Chinese Academy of Sciences on EOR for CCS, biomass gasification and syngas;[205] and the U.S.-China Clean Energy Research Center (CERC), that facilitates joint clean energy R&D on topics such as building energy efficiency, clean coal (including CCS), and clean vehicles.[206] Finally, Qatar also has a stake in discussions at the international level and should therefore ensure that international policy efforts maximize the potential for sharing of knowledge and technologies of mutual benefit, for example, through international research-sharing agreements. Supporting international technology-oriented agreements is crucial and an important complement to other international efforts such as emissions-based agreements.[207]

Public-Private Partnerships for Research, Development, Demonstration and Deployment

The GCC energy sector is unusually active and globalized, and there are significant opportunities for cross-cutting collaboration between private (international) companies, industry and public-private partnerships that could help utilities, governments and private sector partners in several ways. First, by engaging industrial partners, governments can encourage innovation in areas that suit both government goals and private sector interests. Ideally, those partnerships can evolve into broader innovation ecosystems that draw in research partners and global expertise. Second, partnerships can help signal to investors the likely trajectory of energy policy and government priorities in the coming decade. Much of the GCC region's energy consumption occurs in the production and processing of hydrocarbons and other carbon-intensive industrial applications. Even without explicit requirements, the financial incentives to save energy are sometimes large: For example, the opportunity costs of wasting energy assets that could otherwise be sold have prompted many of the multinational companies in these industries to implement efficiency measurement and management processes. An example is ExxonMobil, a major joint-venture investor in the GCC, which has developed a Global Energy Management System (GEMS), a program comprising over 200 best practices and performance measures for process units, major equipment and utility systems in the petrochemicals and petroleum-refining operations. Other oil majors present in the GCC have similar institutionalized efficiency programs. Total, also a major investor in the GCC, has a stated goal to improve the efficiency of its exploration and production and petrochemicals production by 2 percent per year over the period of 2007-2012. In 2008, the company published an Energy Performance Management Guide, aimed at getting its staff to deploy more efficient technologies and management practices. While many of the technical directives and guidelines used by energy companies may be specific to the hydrocarbon production sector, some of the efficiency management systems, data-collection techniques and analysis tools may also be applicable to other sectors economy—such as power generation—currently under state management.

POLICY PROGRAM 2: INDUSTRIAL EFFICIENCY

Given the large amount of heavy industry in the region—energy and petrochemicals in particular—there are potential large gains from even small increases in equipment and process efficiency in industry. As with other areas, a broad set of policies across the sector would be most helpful, focusing not only on technologies but also on moving toward market prices. Government can play a large role in not only setting standards for efficiency but also for ensuring that efficient investments pay off at a market rate. An efficiency program in Qatar and other GCC countries could be constituted of several components.

Lower-Energy Buildings

The share of the residential sector in total electricity consumption exceeds 50 percent in Kuwait, Saudi Arabia and Bahrain, is about 40 percent in the UAE, and is just over 20 percent in Qatar. Moreover, countries in the GCC region are rapidly building out their housing and commercial space, and these buildings could turn into long-term heavy users of energy, particularly for space cooling. This development provides a huge opportunity to improve energy efficiency in the construction and management of buildings that would be important in terms of reduced GHG emissions and would produce cost saving shared by industry and residents. Achieving this energy efficiency outcome could include construction codes or standards for new buildings; building retrofits for improved efficiency; and the incorporation of lower-energy passive measures such as natural ventilation, night ventilation and evaporative cooling.

A necessary component of this transition toward efficient building stocks is to encourage the private sector to be able to make informed decisions about best practices. Rating systems and performance requirements for efficient building materials and accreditations programs such as LEED in the United States and BREEAM in the U.K. can contribute to best practices. In the GCC, the Qatar Sustainability Assessment System (QSAS) created by the BARWA and Qatari Diar Research Institute provides a template for region-specific building-sustainability programs. The QSAS program, which draws on lessons from a range of international frameworks for rating building sustainability and efficiency, offers an accreditation system for buildings that meet a prescribed set of criteria as well as training schemes for professionals in the construction sector. In 2011 portions of the QSAS criteria were incorporated into regulations by the State of Qatar. Abu Dhabi has also launched an initiative for building efficiency through Estidama, its sustainability program. The Estidama Pearl Rating System is a five-point ("pearl") system modeled on the LEED system. According to an executive order, all new buildings in Abu Dhabi must meet the minimum "1-pearl" rating from September 2010; all government buildings must meet the "2-pearl" rating. Such programs could be officially incorporated in all GCC member states, and those countries that have already implemented them could investigate the possibility of requiring more broad-based or ambitious efficiency targets for future projects.

Efficient Appliances and Industrial Equipment

Improving efficiency for appliances, equipment and other technological devices can be assisted with a combination of mandated minimum efficiency standards and voluntary labeling for "quality" products that satisfy certain criteria for excellent performance.

Goals could be benchmarked domestically or relative to regional or international levels. Rating and labeling programs that provide information to the consumer at the point of purchase about the energy usage profiles and long-term energy costs of competing products are other means of improving efficiency. GCC countries have a number of nascent initiatives that can provide the basis for increased adoption of standards in both the building and appliance sectors. The Saudi Arabian Standards Organization (SASO), for example, oversees the implementation and standards of the national energy efficiency appliance labeling program, as well as mandates for appliance efficiency standards. Also, the UAE's Emirates Authority for Standardization and Metrology (ESMA) has launched an efficiency rating system for air conditioners. Systems are rated according to a star system (with five stars being the most efficient), and those that do not meet the minimum requirement are not allowed into the country. The system has been expanded to refrigerators and freezers in 2012 and to washing machines in 2013. The application of such systems by other countries in the GCC would be a major step toward increasing overall energy efficiency.

New Government Institutions to Oversee Efficiency

GCC countries could consider establishing energy efficiency authorities under their existing government energy agencies. Such institutions would be under the control of each government in the region and would have responsibility for managing domestic efficiency-related projects, promoting public-private partnerships and building capacity through the training of technicians and educators. They would also be responsible for coordinating with each other on trans-GCC partnerships. If desired, the role of the efficiency authority could also include responsibility for monitoring and analysis of water usage, including examination of the distribution and desalination systems. There is some foundation for such energy authorities in the region. Saudi Arabia's National Energy Efficiency Program (NEEP), for example, studies the possibility of implementation of energy efficiency measures in Saudi Arabia, and has set targets for reducing the country's energy intensity by 2030. Looking more broadly, India has implemented a successful Bureau of Energy Efficiency that could also serve as a model.

Utility-Driven and Utility-Led Efficiency Programs

Because of their closer contact with consumers, utilities are in a potentially useful position in terms of encouraging residential and commercial energy efficiency. Moreover, energy efficiency is an important utility system resource that also reduces greenhouse gas emissions, achieves savings for customers and generates jobs. Utilities in the GCC could develop programs to encourage upgrades to more efficient appliances, to do energy audits on buildings, or to encourage peak load reductions through technological or behavioral incentives. Moreover, smart grids hold promise to enable improvements in energy efficiency within the utility sector through both gathering information on use and helping to manage demand and load. However, to harness the full efficiency and environmental benefits of smart grids would require careful program design and implementation, as well as targeted capital investment. In the U.S., for example, utilities are by far the largest driver of large-scale electricity efficiency programs, with customer-funded electric efficiency programs available in 44 states. Their budgets totaled over $6.8 billion in 2011.[208]

POLICY PROGRAM 3: ALTERNATIVE SOURCES OF SUPPLY

The GCC region is in a quandary with respect to energy supply: Domestic demand is growing quickly, partly in response to artificially low energy prices, but domestic use is not as profitable as export. Unfortunately, the opportunity cost of this domestic demand is to lower the net level of income from selling resources into the global market. While pricing reform and efficiency policies are necessary components of any comprehensive energy strategy, alternative supply also has a role. By replacing domestic consumption, alternative supply can free up resources for export. Alternatives such as solar, wind and biofuels can also create a lower-emissions energy economy, and thereby lower contributions to global climate change. Providing a domestic market for new technologies can also bolster the research and development of technologies appropriate for the region.

A strategy to enhance the development and deployment of alternative energy technologies in the region needs to establish technical expertise, ensure robust technologies are available at reasonable cost, and create the market and policy conditions to encourage their uptake by the private sector. Such a program could draw from the following recommendations:

Resource Assessment and Data Collection

The ultimate financial return from many renewable energy technologies depends heavily on the quality of the resource—such as wind or solar. Until very recently, little was known about these resources in the GCC because most mapping was done through remote sensing (satellite) data collection and very broad extrapolations from ground measurements. A high priority is, therefore, to continue and expand progress toward resource assessment in the GCC. Recently, resource assessment and mapping has gained significance as part of the GCC region's rapid ongoing adoption of renewable energy sources, such as solar and wind, to complement fossil fuels. In 2012 the UAE Directorate of Energy and Climate Change, Dubai Supreme Council of Energy, and Environment Agency of Abu Dhabi launched the Research Center for Renewable Energy Mapping and Assessment at Masdar Institute,[209] and in 2013-2014 the Masdar Institute developed UAE solar and wind energy resources maps. The UAE Solar Atlas was subsequently made publicly available to the international community through the Global Atlas online portal developed by IRENA.[210] Such programs, as part of a systematic data collection strategy, can greatly enhance siting and assessment of the appropriateness of these technologies. As such, they should retain a high priority for the coming few years as a precursor to broader renewable deployment.

Renewable Requirements

Minimum requirements for the share of renewables can ensure certain milestones are met for renewable energy deployment. In such cases, there has been much discussion of the "feed-in tariffs" which were used frequently in Europe. However, such tariffs may not be effective in many GCC countries because of the more centralized nature of their utilities. One possible alternative approach is the renewable portfolio standard (RPS), which mandates that a certain fraction of utility energy should come from a basket of specific technologies, such as wind and solar, or renewables in general. There is some precedent for RPS implementation in the region, as Abu Dhabi has committed to provide 7 percent of its total power generation capacity from renewable sources by 2020. Another is the creation of sectoral performance standards for electricity generation as a means of promoting the commercialization of CCS. Such standards would require a significant percentage of electricity to be carbon free or to meet specific performance standards. The advantage of sectoral performance standards is that they are technology-neutral—allowing the market to choose which technology to build—and they allow for a more stable investment climate for constructing the large and costly infrastructure that technology such as CCS will require.

Alternative Finance

One potentially attractive way of financing renewable energy projects in the Arab countries is through Sukuk. Sukuk are certificates representing undivided shares in ownership of tangible assets, usufruct and particular projects or special investment activities. For Islamic financial institutions (IFIs) and corporations, Sukuk offer considerable advantages in liquidity management, fundraising, securitization and balance sheet management. For investors, Sukuk offer the ability to invest in a Sharia-compliant asset class with high tradability. This approach could address one of the big private sector obstacles to smaller-scale renewables: the upfront high capital investment cost.

POLICY PROGRAM 4: RESTRUCTURING THE ENERGY MARKET

Energy security and energy prices are important for every country. All governments have an interest in ensuring that their citizens have easy access to energy at a reasonable cost. Moreover, producer countries often have an interest in enabling their citizens to reap the benefits of their own natural resources. At the same time, allowing the market price of energy to diverge from its underlying cost risks locking in energy-intensive technologies that, over time, makes it increasingly costly to move a country's emissions profile onto a more sustainable level consistent with global climate change goals. Additionally, and as discussed, underpriced energy is a subsidy that has significant fiscal costs, and these costs will be magnified for countries such as Qatar that are experiencing rapid population growth.

In fact, worldwide, fossil fuel subsidies have led to investments that depend on low-cost energy. Undoing those investments may have to be a gradual process, but in the long run the economic costs of continuing subsidies is not sustainable for national accounts or the environment. In addition, while some energy sources can compete with fossil fuels at world market prices, subsidized fossil fuels make the barrier to widespread adoption of alternatives very high. While pricing reform is potentially difficult, planning a gradual transition could be in the long-term interests of macroeconomic health as well as cleaner energy use.

It is now well understood that many aspects of energy production and consumption in the GCC could be significantly improved through a policy of greater market-based pricing and reduced subsidization of energy. In parallel with this could be a gradual longer-term shift to a tax on emissions that would provide additional incentives for investments in cleaner technologies, efficiency and CCS. Despite the well-known political challenges associated with pricing reform, there are means of enacting incremental pricing reform that are likely to have less of a disruptive impact than a wholesale move to market pricing. These include a phased adoption of increased end-user pricing; "recycling" the revenues from any price increase to improve efficiency of use; differentiated pricing across different consumer group; and a mechanism for compensating the most economically vulnerable.

Given the nexus between energy and water use in the GCC, any pricing reform policy for electricity must also take into consideration water supplies. Before any implementation of large-scale pricing reform, countries of the GCC could consider conducting research into the consequences of a change in the pricing structure of energy, including the effects of a phase out of subsidies and other adjustments toward a more market-based approach.

POLICY PROGRAM 5: EFFECTIVE GOVERNANCE

Creating effective governance structures and an enabling environment for policy creation and external investment is crucial in sustaining a broad national vision for low carbon development. Creating a single government agency, or an effective interagency process, with overall responsibility for climate change issues resting with an identified body would be an important institutional development for Qatar. It would ensure that the impact of climate change action on all economic sectors is fully taken into account. And by providing the decision makers with information on economy-wide impacts and opportunities should ensure an optimal set of climate change policies.

Developing a single agency or coordinating mechanisms responsible for broad climate change issues would also provide a means for assessing and making decisions about the crosscutting nature and complex interactions between climate change policy and energy technology innovation and development. As this synthesis has made clear, policies such as pricing carbon would lead to reduced GHG emissions and also improve the economics of CCS and incentivize greater energy efficiency. Similarly, a climate fund would have implications for developing clean energy technologies as well as how Qatar engages with other countries and international organizations.

Qatar and the broader GCC area are at a pivotal time in making energy system investment choices that will bind their pathway for the coming decades. In this report, we have reviewed concerns about climate change, and the prospects for CCS, energy efficiency and alternative technologies for Qatar and the rest of the GCC. We have also reviewed appropriate policies in the individual chapters and then integrated them into a broad-based program in this synthesis. An integrated approach targeting select innovation areas, energy regulations, pricing reforms and governance could transform the possibilities for this fast-growing region. These choices have the potential not only to influence domestic economic health and the well-being of their citizens, but also, through technology spillovers and international leadership, influence the technological choices and trajectory of other countries, regions and the globe.

ANNEX 1: KEY COUNTRIES WITH CARBON CAPTURE AND STORAGE DEMONSTRATION PROJECTS[211]

Algeria: Algeria currently has one CCS project in full operation, the In Salah where, since 2004, around 1 million tons per annum of carbon dioxide have been separated from produced gas, transported by pipeline and injected for storage in a deep saline formation. However, in November 2012, BP announced that CO_2 injection at the In Salah CO_2 storage project had been temporarily suspended pending a business decision on whether to continue commercial operation of the storage program at the site.

Australia: Australia is rich in petroleum, natural gas and coal reserves, and is a significant net energy exporter. The country is highly supportive of CCS and has a number of initiatives designed to accelerate the development and demonstration of CCS technologies. Australia also houses the Global CCS Institute, a knowledge-sharing organization that supports CCS projects around the world. A number of CCS projects (commercial, demonstration and R&D) are underway in Australia. These include: Callide Oxyfuel Project, Queensland; CarbonNet Project, Victoria; South West Hub Project, Western Australia; the CO_2CRC Otway Project, Victoria; and Gorgon Project, Western Australia.

Brazil: Petrobras' recent discovery of large offshore oil deposits led to the June 2013 commencement of CO_2 injection for enhanced oil recovery into the offshore pre-salt Santos Basin. This basin lies below 2,100 meters of water and is now the deepest CO_2 injection well in operation. Petrobras is also conducting a pilot experimental site beside an existing CO_2-EOR facility on the Miranga field. The pilot project is for CO_2 separation from natural gas, after which the CO_2 will be injected into a depleted oil reservoir.

Canada: Canada holds the world's third largest oil reserves (175 billion barrels), behind Saudi Arabia and Venezuela, with large reserves of crude oil (from western Canadian oil sands), natural gas and shale gas. It is also a major exporter of energy, with the majority of its crude oil exported to the U.S. Canada has great potential for CO_2 storage, and the country has demonstrated a commitment to CCS as part of its approach to reducing GHG emissions, with over $2 billion Canadian dollars (USD $1.8 billion) allocated for the development of CCS and one of the world's largest operating CCS projects. Canada is home to seven large-scale CCS projects: Two are in the planning phase, four are under construction, and the Weyburn/Midale EOR project in Saskatchewan, the largest of its kind, is operational.

China: As the world's largest producer and consumer of coal, with an estimated 14 percent of the world's total coal reserves (the third largest behind the U.S. and Russia), China is taking a systematic approach to deploying CCS, based on the establishment of a strong R&D base and followed by the rollout of large-scale demonstration projects. CCS has also been supported under China's science and technology programs during the 10th and 11th five-year planning periods, and support for the technology has increased under the current 12th Five-Year Plan. China has set the goal of developing carbon capture experimental projects in the thermal power, coal-chemical, cement and steel sectors and developing fully integrated carbon capture, utilization and storage (CCUS) demonstration projects, with the captured CO_2 to be used for enhanced oil recovery and geological storage. China currently has 11 CCS pilot projects at different stages of development, some of which are currently in operation. The most significant large-scale bids are being led by major state companies. A state power giant, the Huaneng Group, is the biggest driver of CCS, with two fully integrated post-combustion capture pilots—in Beijing, in partnership with Australia's CSIRO agency, and in Shanghai—and construction has begun on its Greengen integrated gasification combined cycle (IGCC) project southeast of Beijing. China's largest coal producer, the Shenhua Group, is leading a coal-to-liquids (CTL) with CCS project in Ordos, Inner Mongolia. Another CTL project by Dow Chemicals and the Shenhua Group, at Yulin in the Shaanxi province, is in the feasibility study stage. With the experience and confidence gained from implementing these pilot projects, there has been significant growth in the number of large-scale fully integrated projects being proposed.

Europe: Europe is home to numerous projects of various scales that have been initiated over the past 20 years. The U.K. and the Netherlands have the largest number of CCS projects in Europe. Although it is not in the European Union, Norway is the most advanced country in Europe in terms of storing CO_2, with Sleipner and Snovhit collectively storing around 1.7 million tons of CO_2 per annum from their natural gas processing activities (see the section on Norway below). Significant projects are also underway in Germany, Spain, Italy, Poland and Romania.

Japan: Japan is focusing on conducting research and experiments on CO_2 separation and capture—mainly post-combustion capture by chemical absorption, which targets natural gas-fired power stations, coal-fired power stations and other facilities. For pre-combustion capture, an IGCC pilot facility has examined chemical and physical absorption. The construction of a demonstration facility is also planned, with a demonstration phase taking place between 2012 and 2020. The Japanese steel industry has also been conducting experiments on hydrogen reduction in a blast furnace, as well as CO_2 separation and capture from blast furnace gas. In addition, Japan CCS Co., Ltd. was established in May 2008 primarily for the purpose of conducting CCS research and development, as well as conducting a feasibility study in Japan. This project will demonstrate a complete CCS system for the first time in Japan.

Malaysia: In 2010, the Ministry of Energy, Green Technology and Water (KeTTHA) partnered with the Global CCS Institute and the Clinton Climate Initiative to produce a CCS scoping study to provide an assessment of the specific potential for CCS in Malaysia. Following this study, KeTTHA partnered with the Global CCS Institute to undertake a capacity assessment and, based on the assessment, to develop the tailored Malaysian CCS Capacity Development Program. The aim of the program is to help Malaysian stakeholders develop awareness, understanding, knowledge and, ultimately, skills in different components of CCS to ensure that Malaysia is well positioned to capitalize on the technology in the future. Several capacity development initiatives have been implemented over the past two years as part of the program as well.

Mexico: Mexico is actively investigating CCS as one of its energy and climate change strategies. Petróleos Mexicanos (PEMEX) is currently undertaking two pilot projects using captured CO_2 for enhanced oil recovery. CFE, PEMEX and the Mario Molina Centre (an environmental NGO based in Mexico) have collaborated on a scoping study for a demonstration facility to capture CO_2 from a major power plant and utilize it for enhanced oil recovery at a nearby oil field. The World Bank is currently developing a feasibility study for this project. As part of the North American Carbon Atlas Partnership, Mexico has completed the National Carbon Storage Atlas. A basin assessment for storing

CO_2 in saline aquifers was undertaken as part of this project. Work is progressing to continue this assessment at a regional and local level.

Norway: Norway is the biggest per capita producer of oil and natural gas outside of the Middle East. As part of its commitment to a carbon-neutral economy, Norway has made CCS one of the "three pillars" of its energy policy, announcing that all new gas-fired power plants will be required to implement CCS. Norway is home to four large-scale CCS projects: the full-scale CO_2 Capture Mongstad (CCM) plant, projected to be one of the world's largest, with full-scale CO_2 collection potentially beginning in 2020; Sleipner CO_2 Injection; Snøhvit CO_2 Injection; and Industrikraft Möre AS Norway. Finally, a study by the European Commission suggested that Norway could recover an additional 4.2 billion barrels of oil while storing 6.2 (gigatons) Gt of CO_2.

Korea: In July 2010, the Korean government announced a national framework to develop CCS, with the aim of developing two commercial-scale plants by 2020. There are two large-scale integrated CCS projects in Korea at the early stages of development. The estimated operation date for their first project (post-combustion on a coal-fired power plant) is 2016, with the second project estimated to become operational in 2018 (pre- or oxy-fuel combustion on a coal-fired power plant or 300 MW IGCC plant).

South Africa: South Africa is actively pursuing CCS as part of its energy and climate change policies. The South African government has established the South African Centre for Carbon Capture and Storage (SACCCS) to investigate the technical feasibility of CCS in South Africa. South Africa's National Climate Change Response Policy, which was endorsed by its Cabinet on October 12, 2012, identified CCS as one of South Africa's eight Near-term Priority Flagship Programs. The CCS Flagship Program will be led by the Department of Energy in partnership with SACCCS. The CO_2 Test Injection Project planned for 2016 is a key focus of CCS in South Africa. The project will look to store in the order of 10,000-50,000 tons of CO_2. SACCCS is undertaking a scoping study, which draws upon domestic and international experiences to construct a business plan that will underpin the test injection.

United States: The United States has 23 large-scale CCS projects in operation or in various stages of development—the greatest number of any country or region. It has also been a leader in CCS-related research, development and demonstration (RD&D). Proposed U.S. Environmental Protection Agency (EPA) rules covering new power plants would essentially block new coal-fired electricity plants or require the use of CCS technology to meet new standards.[212] One of the most well-known large-scale CCS projects in the U.S. is the Kemper County IGCC project, which will capture 3.5 million tons of CO_2 per annum (around 65 percent of the plant's annual CO_2 emissions). CO_2 will be transported via pipeline and used for onshore enhanced oil recovery, and the project is scheduled to become operational in 2014. Another major project is the Texas Clean Energy Project, a 400 MWe IGCC coal-based power plant that will capture 2.5 million tons of CO_2 per annum. Project operations are due to start in 2015.

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ENDNOTES

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62. G-20 countries include Argentina, Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, the U.K. and the U.S.

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