Gulf Research Center

Knowledge for All

Renewable Energy in the GCC Countries

Resources, Potential, and Prospects

Imen Jeridi Bachellerie

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The cover image shows the Beam Down Pilot Project at Masdar City.
Photo Credit: Masdar City

Gulf Research Center

E-mail: info@grc.net

Website: www.grc.net

Jeddah Office
Gulf Research Center
19 Rayat Al-Itehad St
P. O. Box 10501
Jeddah 21443
Kingdom of Saudi Arabia

Dubai Office
Knowledge Corporation
187 Oud Metha Tower, 11th Floor
303 Sheikh Rashid Road
P. O. Box 80942
Dubai, UAE

Geneva Office
Gulf Research Center Foundation
49, Avenue Blanc
CH-1202 Geneva
Switzerland

Cambridge Office
Gulf Research Centre Cambridge
Centre of Islamic Studies
University of Cambridge
Sidgwick Avenue
Cambridge CB3 9DA, UK

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“By publishing this volume, the Gulf Research Center (GRC) seeks to contribute to the enrichment of the reader’s knowledge out of the Center’s strong conviction that ‘knowledge is for all.’”

Dr. Abdulaziz O. Sager
Chairman
Gulf Research Center

About the Gulf Research Center

The Gulf Research Center (GRC) is an independent research institute founded in July 2000 by Dr. Abdulaziz Sager, a Saudi businessman, who realized, in a world of rapid political, social and economic change, the importance of pursuing politically neutral and academically sound research about the Gulf region and disseminating the knowledge obtained as widely as possible. The Center is a non-partisan think-tank, education service provider and consultancy specializing in the Gulf region. The GRC seeks to provide a better understanding of the challenges and prospects of the Gulf region.

To the memory of my father

To my husband, for his patience and support

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Acknowledgments

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Founded in 1925 as Germany's first political foundation, the FES is a private, non-profit organization committed, through its work, which includes a significant study and research component, to promoting pluralism, democracy and international cooperation, as well as supporting sustained economic and social development and contributing to a more sustainable approach towards the environment and natural resources.

We hope this book, which focuses on the use and development of renewable energy in a part of the world usually associated with hydrocarbon-based energy, will contribute to a better understanding of renewable energy issues in the GCC countries and ultimately to a more sustainable approach towards the environment and natural resources – for the benefit of all.

At the Gulf Research Center, I am indebted to Dr. Abdulaziz Sager, founder and Chairman of GRC, for his outstanding support. Thanks are also due to my colleague Naafia Mattoo who patiently helped with the compilation of statistics and bibliographical resources, and to Radhika Menon for the editing and for the attention she has given to this book.

Imen Jeridi Bachellerie

List of Abbreviations

AED	UAE Dirham
Bbl	Barrel
BIPV	Building Integrated Photovoltaics
BOOT	Build-Own-Operate-Transfer
Btu	British thermal unit
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CSP	Concentrated/Concentrating Solar Power
CO_2	Carbon dioxide
COS	Cost of Electricity
CPV	Concentrated Photovoltaic
Dh	UAE Dirham
DLR	German Aerospace Center
DNA	Designated National Authority
DNI	Direct Normal Irradiance
ISCC	Integrated Solar Combined Cycle
EIA	Energy Information Administration
EOR	Enhanced Oil Recovery
EPC	Engineering, Procurement and Construction
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FIT	Feed in tariff
G	Gallon
GBC	Green Building Council
GCC	Gulf Cooperation Council
GD	Gallon per Day
GDP	Gross Domestic Product
GHG	Greenhouse gases

GHI	Global Horizontal Irradiance
GIS	Geographic Information System
GW	Gigawatt
GWh	Gigawat hour
IEA	International Energy Agency
IG	Imperial Gallon
IGD	Imperial Gallon per Day
IPP	Independent Power Production/Plant
IWPP	Independent Water and Power Production/Plant
J	Joule
KD	Kuwaiti Dinar
KSA	Kingdom of Saudi Arabia
KW	Kilowatt
KWh	Kilowatt hour
LCOE	Levelized Cost of Electricity
LEED	Leadership in Energy and Environmental Design
LNG	Liquefied Natural Gas
m^2	Square Meter
m^3	Cubic Meter
Masdar	Abu Dhabi Future Energy Company
MBtu	Million British thermal units
MED	Multiple Effect Distillation
MG	Million Gallons
MIG	Million Imperial Gallons
MIGD	Million Imperial Gallons per Day
Mm^3	Million Cubic Meters
Mt	Million tons
MTOE	Million tons of oil equivalent
MW	Megawatt
MWh	Megawat hours
MSF	Multi Stage Flash
O&M	Operation and Maintenance

PPA	Power Purchase Agreement
PV	Photovoltaic
R&D	Research and Development
RE	Renewable Energy
RES	Renewable Energy Sources
RO	Reverse Osmosis
RSB	Regulation and Supervision Bureau
SR	Saudi Riyal
TPES	Total Primary Energy Supply
TW	Terawatt
TWh	Terawatt hour
UAE	United Arab Emirates
USD	United States Dollar
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

Units

1 GW	= 1 x 10^3 MW = 1 x 10^6 KW = 1 x 10^9 W
1 GWh	= 1 x 10^3 MWh = 1 x 10^6 KWh
1 watt	= 1 joule per second
1 KWh	= 3,600,000 joules
1 GWh	= 3.6 terajoules = 3.6 x 10^{12} joules
1 Mtoe	= 3.968 x 10^7 MBtu = 11,630 GWh
1 bbl	= 5.615 cubic feet (ft^3)
1 m^3	= 220 IG
1 IG	= 1.2 G
1 m^2	= 10.76 square feet (ft^2)

Introduction

The Gulf Cooperation Council (GCC) countries, whose economies depend on hydrocarbons, are burning increasing amounts of these natural resources domestically. While being important oil and gas producers, their rapid socio-economic growth, characterized by increasing population, high rates of urbanization, and substantial industrialization, is transforming them into big energy consumers too. Demand for electricity is soaring; it has nearly doubled during the last decade and will continue to grow inexorably by seven to eight percent annually for several years to come. Indeed, the growing population requires more and more energy for its basic needs: air-conditioning in buildings and potable water, the bulk of which comes from energy-intensive desalination.

Such fast-growing energy needs are putting pressure on the GCC countries' hydrocarbon resources, the looming shortage of which, coupled with their inefficient use or damaging environmental impact, point to the fact that over-reliance on oil and gas is not sustainable. Given that almost all of the energy used in the region comes from the combustion of fossil fuels, whatever alternative the GCC countries decide to opt for, their response ought to promote clean and renewable energy solutions to sustain their development while protecting the environment. This will involve rationalizing use of hydrocarbon energy and, in the mid to long term, transitioning to a non-fossil power system.

The aim of this book is to help identify the potential role that renewable energy sources (RES) can play in the future energy mix of the GCC countries; it looks closely at the major past and present renewable energy initiatives and policies, as well as industrial and research capabilities in the region, with a specific focus on solar and wind energy technologies. In doing so, this study examines the drivers and requirements for the deployment of these energy sources and their possible integration into sectors as different as electricity generation, water desalination or green building.

Illustrated by a wealth of practical cases and studies, and aspiring to be used as a reference book, this study aims to help researchers comprehend the overall capabilities and achievements of the GCC countries in the renewable energy field, so that perspectives on the region's strategic energy issues are objective and sustainable models are encouraged. Even when topics beyond their fields are discussed, researchers from many diverse fields will find the style to be accessible, while information remains detailed and 'technical'. The book's multidisciplinary approach gives voice to all stakeholders without judgment or partisanship, leaving the reader free to form his or her own opinion about the challenges that are at stake, and decide the course of action that is required by the current situation.

Even though the GCC countries are often viewed as a homogeneous region, in issues related to renewable energies, their singularities deserve specific focus. The reader will therefore find a dedicated chapter for each of the six countries. However, while similar general topics concern the author, specific challenges and opportunities may differ from country to country. Indeed, in every chapter, matters related to energy security, water scarcity, CO_2 emissions, Research and Development (R&D), studies and deployments of renewable energy technologies are discussed, in order to highlight the resources, potential and prospects for the development of these technologies in the country. This approach also helps outline complementarities and limitations of resources, and indicates whether integration of regional or global experiences would be feasible or desirable for each of the GCC countries.

At the regional level, the characteristics that are common to the six countries surely reflect, as already mentioned, their similar rapid economic expansion; but they also originate from the fact that power generation in the six countries is mainly oil and gas based. Besides straining reserves, growth in electricity demand is increasing CO_2 emissions, which exacerbates the record high carbon footprint of some of the countries of the region. Indeed, generation of electricity and heat (mainly covering the electricity and water sectors) is by far the largest single producer of CO_2 emissions and was responsible for an average 40 percent of the region's total CO_2 emissions in 2009, surpassing even 50 percent in some countries.

This impact is aggravated by wasteful patterns of consumption; indeed, both households and industries in the GCC countries are intensively consuming electric power, and the built environment is in most cases responsible for over 75 percent of the total electricity demand in each country. These patterns of electricity use are encouraged by the fact that GCC governments heavily subsidize the prices of energy, which has led to growing demand, but also to increasing energy intensity in some cases. At the same time, subsidies constitute a double burden on the budgets of the states: first they make the opportunities to conserve energy less profitable and secondly, they affect negatively their balance of trade. Indeed, the more fossil fuel is consumed domestically to generate electricity, the less is reserved for exports. Besides, in most cases, the power production industry enjoys subsidized fuel prices for its operations, which helps keep the cost of conventional electricity artificially low and constitutes the biggest barrier to the development of renewable energy.

While this situation continues, no sustainable energy project, including RES, will make financial sense and no innovation will affect habits or cause a transition to a new energy system. Instead, these subsidies will continue to shift many sectors away from potential renewable energy applications for which they are suited.

That is unfortunate when we consider the almost limitless solar capital available throughout the year in the region. All GCC countries are blessed with considerable solar energy potential. The levels of insolation (Global or Direct Irradiances - GHI and DNI) in the region are suitable for both photovoltaic and solar thermal technologies; integrated into buildings, deployed in remote rural communities, or used in utility-scale projects, these technologies can play a significant role in addressing growing electricity demand. For instance, solar thermal energy technologies like Concentrating Solar Power (CSP) can increasingly be used in combination with natural gas in Integrated Solar Combined-Cycle facilities. In countries that have large available land areas, such hybrid plants constitute a more sustainable solution for power generation: high temperature steam generated from CSP technologies could feed steam turbines, thus reducing the amount of natural gas required as compared to conventional natural gas based power generation. The intermittency issue of solar energy can also be resolved by back-up from fossil fuel based units.

In general, renewable energy (RE) applications are still limited in the GCC region because, compared to the cost of conventional electricity in these countries, the cost of RE based electricity is still very high. However, ample availability of solar energy – and to some extent wind energy in some GCC countries – coupled with access to financial capital and capacity to invest in clean and renewable technologies offers the region significant opportunities to become a leader in RE industries. In fact, international R&D initiatives and access to intellectual property do appear, in the GCC context, to be critical factors in this prospect. Indeed, as the GCC countries show little willingness to introduce subsidy-cutting policies any time soon, and because their attention is currently focused on social and short-term economic growth issues, only RE innovations – namely those offering cheaper and more efficient solutions to mitigate water scarcity and excessive electricity needs especially during the hot season – will be able to catch the attention of governments and energy stakeholders.

However, if innovation is to emerge and demonstrate its value, proper economic and institutional structures need to be in place. In the competition with subsidized oil and gas energy, the success of renewable energy technologies in the GCC countries will be subject to the ability of each country to introduce supporting policies, including binding targets and financial incentives, as well as regulatory frameworks to encourage deployment and reduce costs.

By putting together and making available to everyone a study that maps out the issues and opportunities related to renewable energy in the region, our hope is to generate new thoughts and discussions. The information presented here has been extracted from diverse sources and placed in the context of each individual country in order to be relevant to a broad spectrum of potential readers. In this sense, we also hope that knowledge of this field, its experts and institutions will inspire our readers to originate new networks and to actively advance the region's capacities.

Chapter One

Bahrain

Overview: Electricity and Water Sector

Expansion in population and economic activities have led Bahrain to experience high annual growth rate of electricity consumption that varied from an average 8 percent from 2000 to 2005 to an average of 11 percent from 2005 to 2010.[1] In 2008, the country had 2,800 megawatts of electricity generation capacity and produced 140 million gallons of desalinated water per day from power stations and water desalination plants that consumed approximately 583 million cubic feet of gas per day in government- and privately-owned installations.[2] However, socio-economic growth caused peak electricity demand to reach 2,812 MW in 2011.[3]

Desalinated water accounts for more than 80 percent of potable water consumption in Bahrain – a proportion that is increasing over time – which is weighing on the energy resources of the country given that desalination is a particularly energy-intensive industry. The daily water production capacity stood at 145 million desalinated water gallons in 2010. According to a Food and Agriculture Organization survey, excessive pumping of groundwater and over-utilization of the

1. Calculation based on Ministry of Electricity and Water statistics available at http://www.mew.gov.bh/default.asp?action=category&id=64
2. Statement of Fahmi Bin Ali Al Jowder, Minister of Works in Charge of Electricity & Water Authority, Kingdom of Bahrain at the founding Conference of the International Renewable Energy Agency (IRENA), Bonn, Germany, January 26, 2009.
3. For electricity statistics, see graphs on Electricity Consumption, Peak Load and Generation Capacity in Bahrain, and for information on water consumption, see Ministry of Electricity and Water website: http://www.mew.gov.bh/default.asp?action=category&id=65 and http://peakwater.org/?p=5374

Dammam aquifer, the principal aquifer in Bahrain, by the agricultural and domestic sectors has led to its gradual depletion and salinization. For example, groundwater depletion reached 96 million cubic meters in 1991/92, up from 40 million cubic meters in the previous year, while desalinated water amounted to 44 million cubic meters in 1991 and 102.4 million cubic meters in 2003. Consequently, the Bahraini government adopted policies to reduce the country's reliance on groundwater by increasing water supply through desalination and wastewater treatment programs.[4]

In the face of rising demand for water and power, the Bahrain government has been working proactively to bring new capacity online through several independent water and power projects (IWPPs), including fostering the privatization of some state-owned electricity and water assets. The country's first Independent Power Project (IPP), owned by Alazl Power Company, started commercial operations in 2006. It is a gas-fired 950MW power plant that accounted for about a third of total generating capacity in 2009. Besides, the previously state-owned Al Had power and water desalination plant was awarded in 2006 to a consortium of private companies, which formed the Al Had Power Company (HPC). Al Had IWPP has a generating capacity of 1,006MW and produces 90 million gallons of desalinated water per day, thus accounting for more than half the water consumption in Bahrain.[5]

With Bahrain's continuously increasing power consumption, the country's Electricity and Water Authority (EWA) considered additional capacity expansions and, in 2008, awarded a third IWPP contract to a consortium of France's GDF Suez and Kuwait's Gulf Investment Corporation. The $2.1 billion IWPP is located at Al-Dour and will produce 1,200 MW of electricity daily as well as 48 million gallons of desalinated water when it is completed and reaches its full capacity in 2011. Consequently, generation capacity will exceed 4,000 MW by the end of 2011 whereas demand will not exceed 3,000 MW. This leaves a comfortable reserve of 1,000 MW that represents 25 percent of total capacity.[6]

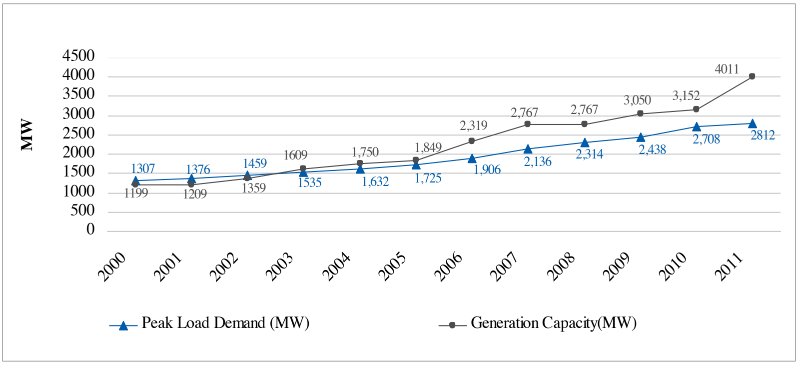
4. Karen Frenken (ed.), *Irrigation in the Middle East Region in Figures*, AQUASTAT Survey – 2008, FAO Land and Water Division (2008); esp. Table 3 and Table 4, 164-5.

5. Utilities-Middle East, "Independents Satisfy Bahraini Needs," in http://www.utilities-me.com/article-67-independents-satisfy-bahraini-needs/; Ministry of Electricity and Water website, http://www.mew.gov.bh/default.asp?action=category&id=64; and US Energy Information Administration (EIA), *Bahrain Analysis Brief*, available at http://www.eia.gov/countries/cab.cfm?fips=BA

6. Utilities-Middle East, "Independents Satisfy Bahraini Needs." Al Dur IWPP will then have added around 50 percent of Bahrain's present electric capacity in two years' time. To this end, GE

As such, Bahrain, which is connected to the GCC electricity grid since 2009, may have the means to fulfill its plan to export up to 100 MW of electricity to other GCC countries.[7]

Bahrain - Electricity Capacity and Peak Load 2000 - 2011



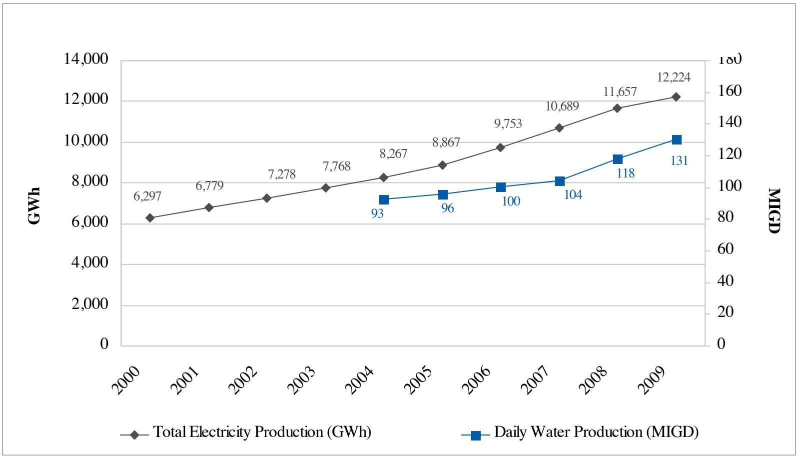
Until 2005, demand outpaced capacity; subsequently, trends were reversed thanks to privatization.
Source: Based on statistics from Bahrain's Central Informatics Organisation and the Ministry of Electricity and Water

However, looking closely into power consumption trends in Bahrain, one sees some room for reducing the electricity load or diversifying its energy sources. Like in most GCC countries, people in Bahrain spend most of their time inside buildings, and this is mostly true for the period from April to November each year, when, for example, electricity consumption per household trebles in comparison with the winter months.

Energy has signed contracts totaling more than $500 million to supply advanced power generation equipment and long-term – 20 years – services for the Al Dur plant. See gulfoilandgas.com, June 11, 2009 in http://www.gulfoilandgas.com/webpro1/MAIN/Mainnews.asp?id=8183 and Geeports.com June 11, 2009 in http://www.gereports.com/from-greenville-to-bahrain-ge-turbines-in-500m-deal/. Also more technical info is available on AME Info: http://www.ameinfo.com/167302.html and from the report on the press conference of the Minister Dr. Abdul Hussain bin Ali Mirza on May 30, 2011 in "His Excellency the Minister Holds a Press Conference Discussing the Plans and the Programs for the Development of the Authority," available at http://www.mew.gov.bh/default.asp?action=article&id=1093

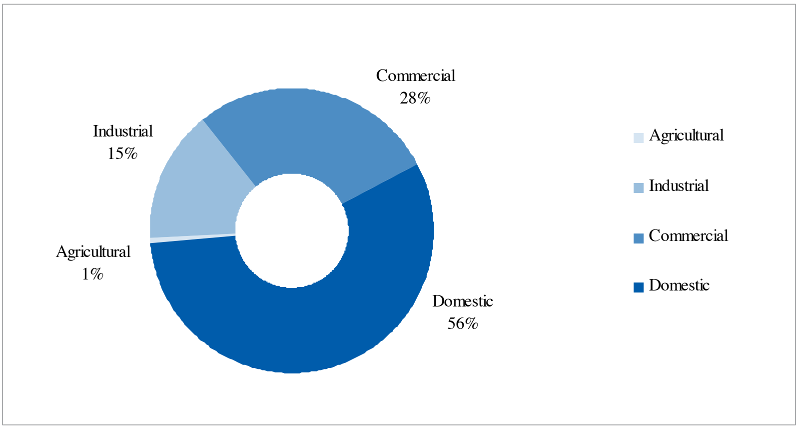
7. Statistics from Bahrain's Electricity and Water Authority: http://www.mew.gov.bh/default.asp?action=category&id=64

Growth in Electricity and Water Consumption - Bahrain



Total electricity and water consumptions show acceleration in growth rate.
Source: Based on Bahrain's Ministry of Electricity and Water Statistics

Electricity Consumption by Sector (%) - 2007



A large majority of the electricity consumed comes from the domestic sector.
Source: Based on statistics from Bahrain's Central Informatics Organisation, *Bahrain in Figures 2007*

In fact, according to EWA statistics, the highest electricity load in Bahrain is consumed by the residential sector (56 percent), followed by the commercial sector (28 percent), and the industrial sector (15 percent). It is estimated that in the built environment, that is mainly residential and commercial buildings, air conditioning accounts for more than 65 percent of electricity consumption. This, in turn, points to the fact that mechanical cooling systems as well as buildings in Bahrain are not energy efficient, thus emphasizing the need for sustainable building design that, besides minimizing the use of fossil-based energy in the construction sector activities in general, should integrate on site renewable electricity generation – like Building Integrating Photovoltaic (BIPV) – and passive solar energy for heating/ cooling systems.[8]

As more than half of the electricity generated is consumed by the residential sector, one can estimate that the latter is responsible for almost 20 percent of the country's total CO_2 emissions.[9] Hence, enhancing the energy performance of the built environment enables fossil fuels saving and the reduction of CO_2 emissions, thus providing strategic economic and environmental rationales for the deployment of renewable energy technologies in this sector.

Mounting Gas Consumption

As Bahrain's economy diversifies and grows, energy consumption is expected to continue growing as a result of increasing natural gas requirements for power plants and the energy-intensive domestic industry.

Indeed, hydrocarbons provide the foundation for Bahrain's two major industries: refining and aluminum smelting. In fact, petroleum production and refining account for more than 60 percent of Bahrain's export receipts and 70 percent of the government revenues. For instance, gas is the main feedstock to Banagas' processing plant to extract propane, butane and naphtha from associated gas (from oil wells); liquefied propane and butane are then transferred to refrigerated storage tanks located at the Sitra port for ship loading, while naphtha is sent to the

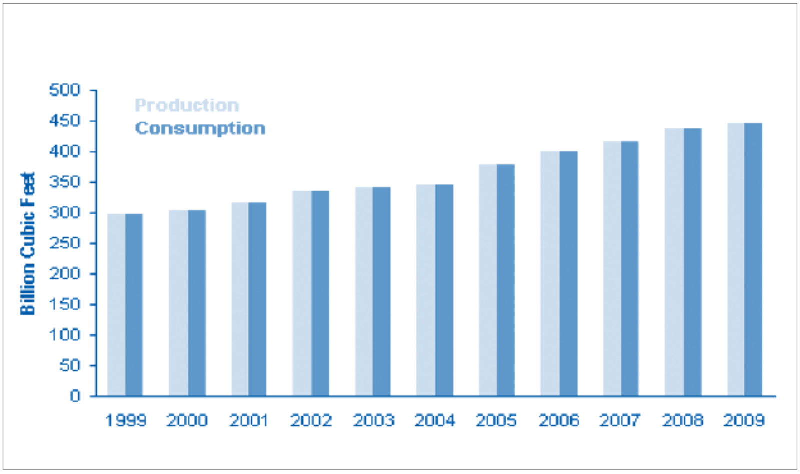
8. Buildings' energy consumption trends in N.W. Alnaser and R. Flanagan, "The Need for Sustainable Buildings Construction in the Kingdom of Bahrain," *Building and Environment* 42 (2007); and Hassan Radhi, "A Systematic Methodology for Optimizing the Energy Performance of Buildings in Bahrain," *Energy and Buildings* 40 (2008). Electricity consumption by sector in Central Informatics Organization based on EWA electricity statistics, *Bahrain in Figures 2007-2008*, available at http://www.cio.gov.bh/CIO_ARA/English/Publications/Bahrain%20in%20Figure/BIF2007_2008.pdf ; and EWA Statistics on http://www.mew.gov.bh/ar/media/pdf/statistics2007/electricity.pdf

9. Author's calculation, based on figures from the International Energy Agency, in *IEA CO_2 Highlights 2011* and EWA statistics for electricity consumption by sector in Bahrain, in *Bahrain in Figures 2007-2008.*

Bahrain Petroleum Refinery (BAPCO) for storage and subsequent export.[10]

Similarly, Bahrain is home to the world's largest aluminum smelter, Aluminium Bahrain, commonly known as Alba. The smelter's energy intensive activity is supported by the company's own power plant, which uses gas-fired combined cycle turbines and has a total generating capacity of 2,200 MW. At times when the country's power demand exceeds its capacity, namely during the summer months between June and September, EWA has imported electricity from Alba's network.[11]

Bahrain's Natural Gas Production and Consumption, 1999 - 2009



Source: Energy Information Administration

More generally, Bahrain's total energy consumption needs are met, to a large extent, by natural gas, with the remainder supplied by oil (85 percent and 15 percent, respectively). Hence, the fact that all of Bahrain's electricity generating capacity comes from conventional thermal sources, mostly natural gas, is directly contributing to the rapid growth of gas consumption in the country. Over the last

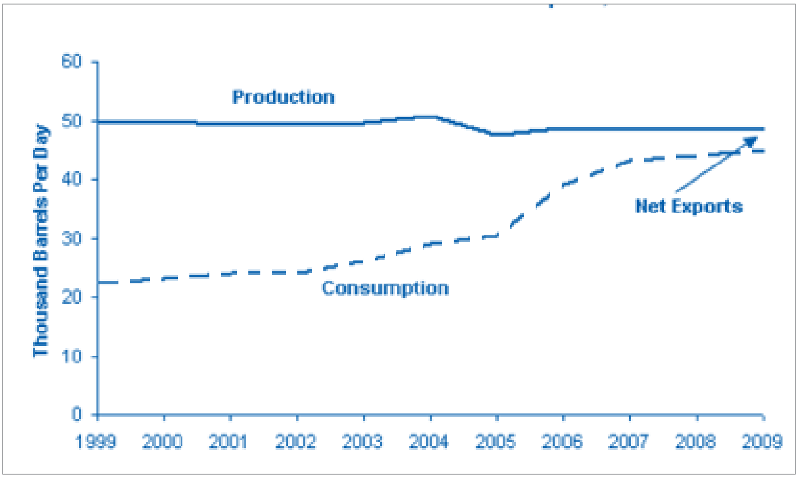
10. The two-train gas processing plant of Banagas has the capacity to process 300 million cubic feet of gas per day. See EIA *Bahrain's Energy Profile*, in http://www.eia.gov/countries/cab.cfm?fips=BA

11. Combined cycle turbines burn natural gas to generate electricity. The waste heat generated by this process is used to make steam that turns the gas turbines and to generate additional electricity without burning any additional natural gas; Source: Alba website: http://www.aluminiumbahrain.com/en/default.asp?action=article&id=224

five years, the average annual rate of growth of gas consumption has been five percent.[12] So unless it is able to increase its own production, Bahrain will need to import natural gas supplies from its neighbors to meet future power needs.

Moreover, being a small producer of oil, Bahrain's oil exports are expected to continue to decrease; they actually registered a fall from 27,000bbl/d in 2005 to 3,000bbl/d in 2009. In 2009, Bahrain produced and consumed 444 billion cubic feet (Bcf) of natural gas, 48 percent of which was dedicated to electricity generation and water desalination.[13]

Bahrain's Total Oil Production and Consumption, 1999 - 2009



Source: Energy Information Administration

Hence, to sustain an economy that depends heavily on hydrocarbon refining and exports, and to prevent over-reliance on hydrocarbon imports, Bahrain should seek to promote alternative sources of energy for its power and desalination sectors. All the more so, because deals with Qatar and Iran about possible imports of gas have stalled and are unlikely to materialize for some years.[14]

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12. According to EIA, Bahrain's proven natural gas reserves stood at 3.25 trillion cubic feet (Tcf) as of January 2011. See *Bahrain's Energy Profile,* available at http://www.eia.gov/countries/cab.cfm?fips=BA

13. Author's calculation based on EIA statistics.

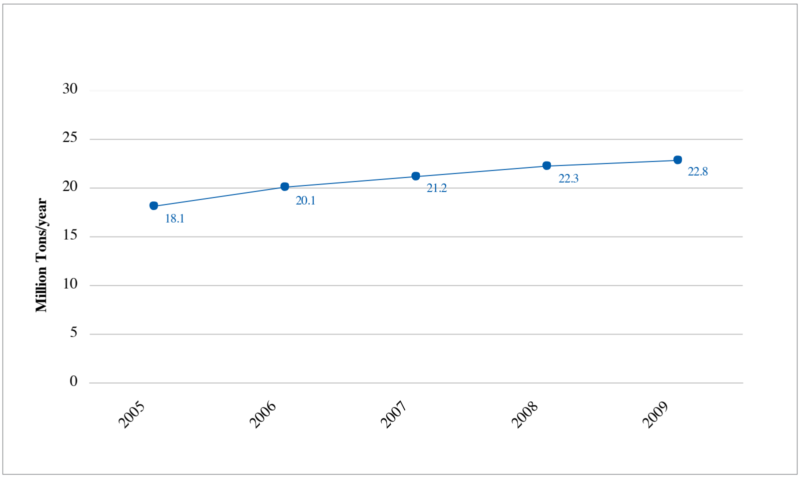
14. Renewable Energy and Energy Efficiency Partnership, Policy database for Bahrain 2010, available at http://www.reeep.org/index.php?id=9353&text=policy-database&special=viewitem&cid=107

Bahrain is consequently bound to strategize its development on a strict rational-use-of-energy paradigm.

Sustainability and CO_2 Emissions

Renewable Energy Sources (RES) like solar and to some extent wind can help reduce the electricity load in Bahrain and mitigate its rising hydrocarbon consumption. It has also been demonstrated that not only the built environment electrification but the highly power-consuming desalination industry too can benefit from integrating different renewable energy technologies into their structures and installations.

Bahrain CO_2 Emissions 2005 - 2009



There has been an increase in Bahrain total CO_2 emissions at an average annual growth rate of 6.5 percent for the past five years. This increase is also seen in the per capita emissions, which grew at average annual rate of 3.9 percent for the same period.
Source: Based on IEA, *CO_2 Highlights* (2011)

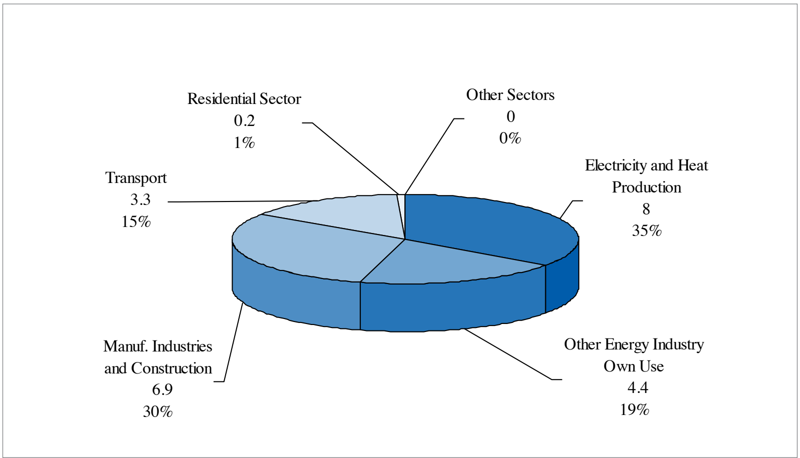
Moreover, convinced that reducing fossil-based energy consumption will have a positive impact on the environment, government officials have acknowledged that the deployment of RES in Bahrain will help reduce the pollution emitted from power generation plants operating with natural gas and diesel fuel.[15] In fact, Bahrain

15. Statement of Fahmi bin Ali Al Jowder, Minister of Works in charge of Electricity & Water Authority, Kingdom of Bahrain at EU-Mediterranean-Gulf Renewable Energy Conference –

ratified the Kyoto Protocol in May 2006 and signed the statute for the International Renewable Energy Agency (IRENA). It has also established a Designated National Authority (DNA) for potential consideration of energy projects within the Clean Development Mechanism (CDM).[16]

Two important conferences took place in Bahrain during 2010 where issues facing the global energy sector, including climate change, sustainability, energy diversification, renewable energy sources, and clean technologies were debated. "The Energy Evolution Middle East Conference" and the "Consultation Meeting on Climate Change Impacts in the Arab Region" were both inaugurated by Dr. Abdul Hussain bin Ali Mirza, Minister of Oil and Gas Affairs, and chairman of National Oil and Gas Authority (NOGA).

Bahrain CO_2 Emissions from Fuel Combustion in 2009 by Sector (million tons)



Around 80 percent of electricity consumption is due to the built environment in Bahrain, where power production accounts for 35 percent of Bahrain's total CO_2 emissions. Source: Based on IEA, *CO2 Highlights* (2011)

In his inaugural remarks, he firmly stressed the importance of a sustainable approach to the development of the energy sector and stated that Bahrain's NOGA

09/10/2009 Brussels, Belgium, http://ec.europa.eu/external_relations/energy/events/renewable_energy_conference_2009/index_en.htm

16. IRENA is an intergovernmental organization established to promote the use of energy from renewable sources on a global scale. It is headquartered in Abu Dhabi, UAE.

and BAPCO were supporting environmental projects such as Clean Development Mechanism (CDM) projects that limit CO_2 emissions, improving energy efficiency, and promoting renewable energy sources. More recently, at the launch of the NOGA study on "Current Environmental Challenges Facing Bahrain's Oil Sector and Ways to Respond to Them," the minister reiterated that NOGA-affiliated companies, including BAPCO, the Gulf Petrochemicals Industries Company (GPIC), and Bahrain National Gas Company (Banagas) all have experience in supporting environment-friendly projects and implementing international green standards and techniques. In fact, in a move to carry forward the "green policy" within Bahrain's oil and gas sector, NOGA signed a framework agreement with Abu Dhabi-based Masdar in 2009 to work together on projects that help reduce carbon emissions under the Kyoto Protocol's Clean Development Mechanism (CDM).[17]

Potential of Renewable Energy Sources (RES)

Since the 1990s, researchers associated with the University of Bahrain (UoB) have conducted several studies in the area of renewable energies – mainly solar and wind – and encouraged the use of these resources in electricity generation or water desalination as an alternative to fossil fuels. Assessments, conferences, workshops, and demonstration projects promoting RES have been conducted in Bahrain by faculty members from UoB's different departments or by foreign universities.[18]

The Engineering Faculty of the University of Bahrain (UoB) has been involved in small-scale R&D projects including the design and construction of a mobile solar water desalination unit which can produce 250 gallons using 1.5kW of photovoltaic panels; and, in collaboration with Long International, they designed a hybrid solar/wind power generation system using 1.9KW of photovoltaic panels

17. Arab Climate Resilience Initiative, *Report of the Consultation Meeting on Climate Change Impacts in the Arab Region: Towards Sustainable Energy - Resources, Challenges and Opportunities*. NOGA study reported in "Oil Sector Challenges Focus of Noga Study," in Gulf in the Media, August 7, 2011. NOGA's CDM announcement was made by Abdul Hussain Bin Ali Mirza, Minister of Oil and Gas Affairs, and Chairman of NOGA, in 2009. Bahrain has so far not registered any projects for consideration in the Clean Development Mechanism; Norton Rose - International Legal Practice, *Renewable Energy in Bahrain,* January 2011,

18. For more information on this research, please refer to the bibliography section of Bahrain.

and a 100W wind turbine.[19] The applicability of certain solar water heating systems has also been studied and experimental units constructed to test their performance and cost effectiveness under Bahrain weather conditions.[20]

Specifically, besides these demonstration projects, solar and wind physical potentials were assessed in a number of studies the findings of which we present in the following sections.

Solar Energy

Located between latitudes 25º32′ and 26º20′ and longitudes 50º20′ and 50º50′, Bahrain is an archipelago of 35 islands, and has an arid to extremely arid environment, characterized by high temperatures, scanty rainfall, and high humidity levels due to the surrounding Gulf waters.[21] The country has abundant insolation and hence high solar energy performance indicators. The Global Horizontal Irradiance (GHI) – which defines the average electricity yield from Photovoltaic power systems – is nearly 2,160 kWh/m^2/year and the Direct Normal Irradiance – useful for Concentrating Solar Thermal Power CSP) systems – is 2,050 KWh/m^2/year. It is worth mentioning here that GHI and DNI were assessed for a fixed surface tilted south according to the local latitude angle and for surfaces tracking the sun, respectively.[22]

More specifically, the performance indicators for GHI and DNI at Bahrain International Airport were closely measured for different periods of the year and were found to be highest between April and September; their values were highest in June and the lowest in December. DNI was found to constitute 79 percent of GHI value in June but only 55 percent of the latter in December. On average, the GHI

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19. For more information on the Desalination unit, see Haitham Al-Qahtani, "Feasibility of Utilizing Solar Energy to Power Reverse Osmosis Domestic Unit to Desalinate Water in the State of Bahrain," World Renewable Energy Council WREC 1996; and for the hybrid system, see W.E. Alnaser, "Mobile Solar and Wind-powered Generator (MSWPG)," *Applied Energy* 64 (1999): 97–105.

20. A. A. Karaghouli and W. E. Alnaser, "Experimental Study on Thermosyphon Solar Water Heater in Bahrain," *Renewable Energy* 24, Issues 3-4 (November 2001): 389-396; and Hussain Al-Madani, "The Performance of a Cylindrical Solar Water Heater," *Renewable Energy* 31, Issue 11 (September 2006): 1751-1763.

21. Temperature averages from 17 °C in winter (December–March) to 35 °C in summer (June–September). The rainy season runs from November to April, with an annual average of 83 mm. Mean annual relative humidity is over 67 percent. Source: AQUASTAT report FAO (2008).

22. German Aerospace Center (DLR), *Concentrating Solar Power for the Mediterranean Region* (2005), 55-57.

amounted to 6.25KW/m^2/day and the DNI to only 4.28 KWh/m^2/day.[23]

Based on DNI and CSP site mapping conducted by the German Aerospace Center (DLR), and taking into account sites with DNI superior to 2000 KWh/m^2/year, it was found that Bahrain has an economic potential of 33 TWh/year of solar thermal (CSP) power supply.[24] However, it should be mentioned here that Bahrain electricity demand reached 13.756 TWh in 2010, which is a bit more than 41 percent of its CSP annual potential.[25]

Similarly, GHI values for differently tilted surfaces were thoroughly compiled in Bahrain; this exercise determined the variance of the incident solar radiance according to the surface orientation. The study conducted for this purpose found that the monthly average insolation on vertical south facing surface was 3.22 KWh/m^2/day – reaching a maximum of 5KWh/m^2/day in winter – which is larger than the figures found for West, East or North surfaces.[26] Such a compilation actually provides a means of sizing up the passive insolation on buildings, a phenomenon that makes demand for air-conditioning even higher, especially when the adopted architectural designs are not adapted to the local weather conditions.

Prospects for Building-Integrated Photovoltaics (BIPV)

The fact that buildings in Bahrain are not energy-efficient, and the growing tr end of using solar energy to enhance the built environment sustainability, have motivated studies on the prospects and constraints of implementing Building-

23. 22.5 Mj/m^2 and 15.40 Mj/m^2 respectively; On the variation of the diffuse, direct or total (diffuse + direct) solar irradiations in Bahrain, see T. Muneer, W.E. Alnaser, F. Fairooz, "The Insolation on Vertical Surface Having Different Directions in the Kingdom of Bahrain," *Desalination* 209 (2007): 269-274.

24. According to DLR: "The technical potentials are those which in principle could be accessed for power generation by the present state of the art technology. The economic potentials are those with sufficiently high performance indicator that will allow new plants in the medium and long term to become competitive with other renewable and conventional power source, considering their potential technical development and economies;" in German Aerospace Center (DLR), Institute of Technical Thermodynamics, Section Systems and Technology Assessment, Concentrating Solar Power for the Mediterranean Region (2005), 55 and 56.

25. Ministry of Electricity and Water statistics at: http://www.mew.gov.bh/default.asp?action=category&id=64

26. Muneer, Alnaser, Fairooz, "The Insolation on Vertical Surface," 273. For more information on insolation and extractable solar electricity from four vertical surfaces having different geographical orientations and displaying PV panels with efficiency of 15 percent, see N.W. Alnaser, R. Flanagan, and W.E. Alnaser, "Potential of Making-over to Sustainable Buildings in the Kingdom of Bahrain," *Energy and Buildings* 40 (2008): 1304-1323; p.1312.

Integrating Photovoltaics (BIPV) – and to a lesser extent, Wind Energy (BIWE) – in the design and the construction industry of Bahrain. According to these studies, high insolation rates in Bahrain are favorable not only for solar thermal devices (especially for water heating) but also for PV panels to be installed on the roofs or used in the structure of the buildings. Moreover, it was estimated that up to 30 percent of the electricity consumption in the built environment could be produced by BIPV.

A study conducted in 2007 by the University of Reading, UK, used questionnaires to ask decision-makers, architects, and contractors in Bahrain about the constraints in disseminating BIPV or BIWE in the country. For the first group, the most striking constraints linked to the technology aspects of this issue are the non-availability of expertise in Bahrain and the high initial cost of BIPV. For the second group, these technological constraints revolve around lack of education and knowledge of sustainable design, lack of information on cost of electrical unit (kWh) of the solar and wind energy compared to conventional energy, as well as the life cycle costs of the PV and wind turbines systems; however, the third group found that technology constraints can be overcome by sub-contracting, or else by training the engineers if subsidized cost is provided for this purpose.[27]

Putting aside the constraints highlighted previously, one can still question the considerably high ene rgy-inefficiency of existing designs and buildings in Bahrain and most GCC countries, where air-conditioning accounts for 70-80 percent of their lifetime total energy consumption. There is much scope for technical and political actions that promote energy efficiency in the built environment. As some studies emphasize, tools and methodologies for energy evaluation and optimization in buildings need to be adopted, and the government targets for CO_2 emissions reduction should be reached through reducing the buildings' reliance on conventional electricity.[28]

In another study jointly conducted by the University of Reading and the University of Bahrain, the authors analyzed the advantages of a make-over for two large constructions in Bahrain – Almoayad Tower and Bahrain International Circuit (BIC) – where the renovation would be in the form of using PV on façades and rooftops. The amount of electricity extracted from such would-be BIPVs has been studied; for Almoayad Tower, the annual solar electricity produced from PV panels

27. Alnaser and Flanagan, "The Need for Sustainable Buildings Construction."

28. Radhi, "A Systematic Methodology for Optimizing the Energy Performance of Buildings in Bahrain," 1297-1303; Alnaser, Flanagan, Alnaser, "Model for Calculating the Sustainable Building Index (SBI)," 2037-2043.

installed on the roof and four facades would amount to 3 million KWh, which corresponds to annual CO_2 emission reduction of 3,000 tons. It has been underlined that with such production, the owner can sell electricity to the utility or else obtain Euro 30,000 worth of Certificates of Emission Reduction annually.[29] For the BIC building, the total annual electrical power from PV panels installed on windows and roofs will be nearly 48 million KWh, corresponding to 48,000 tons of CO_2 emission saving per year (assuming each KWh of energy from natural gas leads to emitting 1 kg of CO_2).[30]

Although Bahrain has a very high solar potential, and despite the huge electricity needs of its built environment, construction projects and buildings do not harness this source of energy, though thermal heating/cooling devices and PV panels can be installed on roofs and offer huge electricity saving potential. If solar water heating is used in all the buildings in the country, up to 10 percent of the consumed electricity can be saved.[31]

The first and only building – and project – in Bahrain where electrical power came partially from renewable energy sources was the Bahrain World Trade Center building (BWTC) which makes use of three parallel wind turbines. The total power output of these three turbines is 0.66 MW, providing only 11-15 percent of the 240 m high twin towers' energy requirements, and it was estimated that the energy they yield should amount to between 1,100-1,300 MWh per year which would save at 2,000 kg of CO_2 as compared to an equivalent gas electricity generation process. As an energy-intensive building though, the BWTC is not considered to be a low carbon emission project by European or other international standards.[32]

Wind Energy

Measurements undertaken by the Meteorological Directorate indicate that the average annual wind speed in Bahrain at 10m height is 4.8 m/s, but other studies put the country's average wind speed between 5 and 6m/s with a north-to-

29. For the make-over, the authors assume that the efficiency of PV cells is 20 percent; Alnaser, Flanagan, and Alnaser, "Potential of Making-over to Sustainable Buildings," 1304-1323; 1309 and 1315.

30. Ibid., 1321-1322.

31. Alnaser and Flanagan, "The Need for Sustainable Buildings Construction."

32. The BWTC building's wind turbines received the official certification by Bahrain Electricity Distribution Directorate (EDD) in February 2009; see http://www.bahrainwtc.com ; see also N.W. Alnaser, "Towards Sustainable Buildings in Bahrain, Kuwait and United Arab Emirates", *The Open Construction and Building Technology Journal* 2 (2008): 30-45.

north-west direction. In both cases, this is considered to be moderate, especially because in Bahrain the Full Load Hours of wind per year do not exceed 1,360 h/y, which is not considered to be an economically viable wind energy potential. Furthermore, the economic potential for electricity supply from wind does not exceed 0.1 TWh/year which is the lowest in all the Middle East and North Africa region. [33]

Despite these indicators, a study was carried out to investigate the geographical distribution of wind power (wind atlas) and the relation between the latter and the seasonal electricity load. The study found that – at 60m height – the annual mean wind speed is 6.93m/s with annual mean power density of 440W/m^2 and capacity factor of 29 percent; it concluded that this showed good wind potential and fairly strong enough winds of long duration favorable for generating wind energy. In particular, it was found that the central and southern parts of the main island of Bahrain have the highest wind power density and could be considered favorable for wind power production. However, a certain mismatch between monthly mean electricity demand and wind speed has been observed, namely the maximum wind occurs during the month of January when the lowest power demands were registered. Finally, the study recommended applying the potential of wind power in Bahrain to the country's Reverse Osmosis (RO) desalination plants – as a controllable load – for a smooth integration of wind power into the Bahrain power supply system.[34]

On the other hand, analyzing the wind data at heights of 10m, 30 m and 60 m, another study found that the maximum power densities were registered in February and amounted to 164.33 W/m^2, 624.17 W/m^2 and 1171.18 W/m^2, respectively; while the minimum power density, recorded in October, were 65.33 W/m^2, 244.33 W/m^2 and 454.53 W/m^2, respectively. The average annual wind power density was found to be 114.54 W/m^2 for 10 m height, 433.29 W/m^2 for 30 m height, and 816.70 W/m^2 for 60 m height. In summary, the study presents a detailed statistical analysis of wind speed and power at these different heights, as well as the capacity factor variation of different matching wind turbines, in order to ensure an optimum plan for wind power stations in Bahrain. Since the large number of low rated wind generators would occupy a large area, and as the

33. DLR, *Concentrating Solar Power*, 57.

34. Hanan Al Buflasa, David Infield, Simon Watson, Murray Thomson, "Wind Resource Assessment for the Kingdom of Bahrain," *Wind Engineering* 32, no. 5 (October 2008); and Hanan Al Buflasa, Murray Thomson, David Infield, Simon Watson, "Feasibility Study of Wind Power in the Kingdom of Bahrain" available at http://www.docstoc.com/docs/2382570/FEASIBILITY-STUDY-OF-WIND-POWER-IN-THE-KINGDOM-OF-BAHRAIN-Hanan-Al

area of Bahrain is estimated as 665 km^2, such factors need to be considered in planning and selecting the turbines, the study stresses.[35]

Hesitant Steps towards Renewable Energy

Targets and Projected Deployments

Despite the various and encouraging results from the experimental installations and studies on solar and wind energy potentials in Bahrain, there is as yet hardly any installed wind and solar capacity in the country. This is reflective of the prevalence of fossil fuels as well as the absence of strategies that promote renewable electricity production at small- or large-scale levels. It should be noticed here that constraint of space in Bahrain reduces the prospects of large solar technology deployments in particular. More generally though, when compared with fossil fuel electricity generation, cost issues associated with solar and wind technologies remain the major challenge for their deployment. In Bahrain, as with other GCC countries, electricity production from fossil fuel is heavily subsidized and supplied at a price which is less than the cost of generation. In comparison, RE based electricity is not competitive.

Nevertheless, faced with harsh climate conditions, water scarcity, limited hydrocarbon reserves and environmental challenges, Bahrain with the help of the World Bank, engaged in 2008 in defining a strategy for developing and using alternative energy sources as an integrated component of energy supply for its own use or for other countries in the region.[36]

As far as RES are concerned, EWA expressed the need to promote such technologies and took the initiative to form a committee to conduct a study of solar and wind energy resources in Bahrain and the possibility of utilizing them for the production of electricity and desalinated water. The committee comprised the Industry and Commerce Ministry, the National Oil and Gas Authority (NOGA), the Bahrain Petroleum Company-BAPCO, Alba, the University of Bahrain, and the Public Commission for the Protection of Marine Resources, Environment and Wildlife. The committee completed the survey by the end of 2008 and drew up a plan to develop two solar and wind energy projects that should enable Bahrain to use renewable energy sources by 2012.[37]

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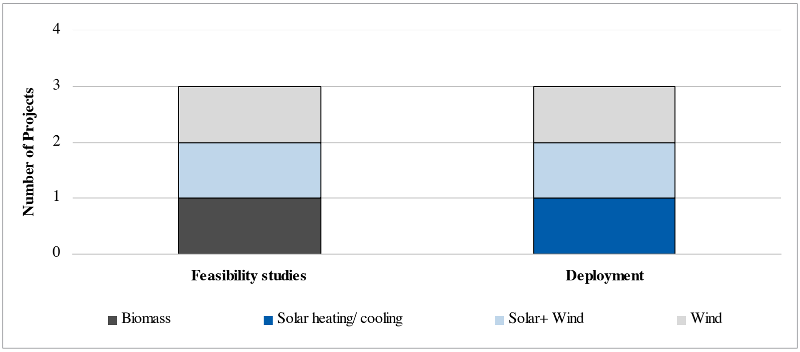
35. Fawzi A.L. Al Jowder, "Wind Power Analysis and Site Matching of Wind Turbine Generators in Kingdom of Bahrain," *Applied Energy* 86 (2009).

36. Ibid.

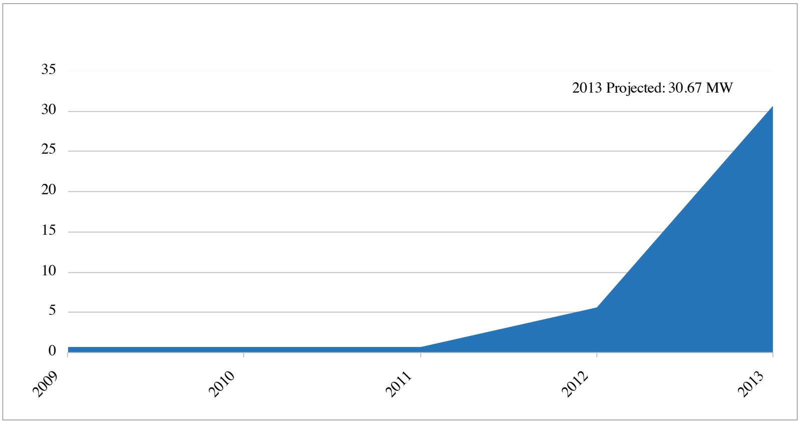
37. Dr Abdul Majeed Ali Alawadhi, CEO of the EWA, in August 2009 in "Bahrain to

Number of Renewable Energy Projects in Bahrain per Nature and Technology (up to 2013)



Source: Author's calculation

RES Projects Bahrain - Cumulative Capacity (MW)



Number of projects deploying RE technologies is limited in Bahrain, and cumulative capacity, if installed by 2013, is negligible comparing to the present conventional power capacity (0.7 percent). RE announced targets are not included.
Source: Author's calculation

In 2009, Bahraini experts suggested that up to 1,000 MW of Bahrain's future electricity demand could be met by renewable energy and that eventually the country would have to invest $900 million in such projects during 2010-2020 to

Use Renewable Energy in 3 Years," available at:http://www.thefreelibrary.com/Bahrain+to+use+renewable+energy+in+3+years.-a0205071603 meet the growing demand for energy. In this context, a 700 MW offshore wind electricity generation project using 100 wind turbines was prospected to be fully designed and implemented by BARD Engineering. However, so far there have been no developments on this front.[38]

On the other hand, at the end of July 2011, the Bahraini Ministry of Energy contracted Fichtner Consulting Engineers of Germany to "provide full consultancy services to the Authority [EWA] for the development of Renewable Energy projects."[39] These services should include investigations, field measurements, data collection & verification, preparation of detailed techno-commercial feasibility study for solar and wind resources in the Kingdom to determine their adequacy, designs/engineering works, tendering, site supervision and overall project management for the construction of a grid-interactive solar and wind pilot power plants. These plants would produce up to 5MW of [hybrid solar/wind] power and allow integration with the existing generation. The pilot plants are expected to start operations in the first quarter of 2013.[40]

Such a would-be demonstration project is mainly meant for R&D activities on solar and wind technologies and for evaluating their technical and economic viability for subsequent large-scale deployments in the future. Indeed, it has been announced that Bahrain aims to produce five percent of its energy from renewable sources by 2030.

However, in early 2010, an official from Bahrain's Ministry of Finance stated that the government's priority was to focus on developing clean technology projects – which utilize mature existing technologies like energy efficiency measures and waste-to-energy processes – rather than commit to a strategy of developing large-scale solar and wind projects or develop a specific renewable energy scheme to support the deployment of such technologies. In this context, a planned 25 MW waste-to-energy plant in Askar, on the east coast of Bahrain, was awarded by the Bahraini Ministry of Finance to France's Constructions Industrielles de la Méditerranée (CNIM) on a build-operate-transfer (BOT) basis to install the facility.

38. W.E Al Nasser, Bahrain chapter of the International Solar Energy Society Conference UNIDO in Bahrain, February 2009. For more technical information on the wind project, see W.E. Al Naser and N.W. Al Naser, "Solar and Wind Energy Potential in GCC Countries and some Related Projects," *Journal of Renewable and Sustainable Energy* 1, 022301 (2009).

39. EWA News and Events, "H.E. The Ministry of Energy Signs a Contract for Conducting Feasibility Study for Renewable Energies and Supervision of Establishment of a Pilot Power Plant," available at: http://www.mew.gov.bh/default.asp?action=article&id=110

40. Ibid.

The project will incinerate 390,000 tons of domestic waste from Manama annually and will have a generating capacity of 25 MW that will feed into Bahrain's electricity grid. The plant is likely to start operations in 2013.[41]

On the nuclear front, Fahmi Al Jawder, Minister for Electricity and Water Affairs declared in December 2010 that Bahrain plans "to have nuclear power by 2017."[42] In parallel, however, Bahrain – with the help of the United Nations Development Program (UNDP) and NOGA – is considering the setting up of a governmental think-tank to explore the prospects of renewable energy resources, energy conservation, clean technologies and the creation of associated job opportunities in the country and the region.[43]

Eco-friendly Investments and Strategies

With environment-friendly and sustainability paradigms in mind, and taking into account that "technological breakthroughs have been achieved to increase the use of renewable energy sources," the Bahraini Minister of Oil and Gas Affairs, Dr. Abdul Hussain Bin Ali Mirza, stated that NOGA and BAPCO are moving to a vision of renewable energy and have started "exploring, surveying, and evaluating the capabilities and potentialities in the area of [solar and wind] energy sources".[44]

In this context, NOGA has initiated a pilot solar project in cooperation with a US company Petrosolar to explore the option of solar energy generation in Bahrain and conduct a feasibility study of running "every house in Awali area on solar energy." Results of this study have not been made available. The study seems to have been expanded recently to BAPCO refinery as well as to the company's fuel and service stations. According to Dr. Mirza, it will still "take a while to implement the project since a lot of other procedures have to be taken into account [only] if the project is found to be feasible."[45]

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41. Norton Rose International Legal Practice, January 2011.
42. Reuters, "Bahrain Plans to Use Nuclear Power by 2017," December 23, 2010. According to the Renewable Energy and Energy Efficiency website, "Plans to implement nuclear power in the country have faced some problems due to a lack of local experience and the high demand for nuclear expertise in the area."
43. "Bahrain Plans 'Green' Energy Think-tank," http://www.businesstoday-eg.com/environment/middle-east/bahrain-plans-green-energy-think-tank.html and UNDP website at http://www.undp.org.bh/energyandenv.html
44. Opening Address by Abdul Hussain Bin Ali Mirza, Minister of Oil and Gas Affairs, chairman of NOGA, at the "Energy Evolution Middle East," Bahrain, May 17-19, 2010.
45. Trade Arabia Business News Information, "Bahrain to Expand Solar Project," May 28, 2011;

In the meantime, NOGA has also engaged a Japanese company to evaluate wind velocity in Bahrain in order to set up a wind energy plant to produce electricity. The project is still in its early stages, but one can expect that the general political upheaval that unfolded in Bahrain at the beginning of 2011 would delay the implementation of such projects. In any case, it is expected that the prospected project would be developed as an IPP.[46]

On a rather different scale, the national oil company BAPCO has launched a R&D program in the field of solar and wind energy. For instance, in collaboration with the German Heliocentris, a Berlin-based specialist for clean energy storage solutions, BAPCO has installed a fully-integrated autonomous energy system receiving input from a 4KW photovoltaic array and a 1.7 KW wind generator. The system stores energy by generating hydrogen. The hydrogen is then converted by a 1.2KW fuel cell module into electricity. The total output of the system – 5KW – is used to power the lighting and equipment of a showcase laboratory.[47]

All these expressions of interest towards RE technologies may be traced to the sustainability imperative that the energy sector stakeholders are required to address as a result of the environment and energy preservation challenges facing the country; However, for the time being, one only notices the quasi-absence or slow pace of project implementations and the fact that, despite the strong interest in the utilization of solar and wind energy sources expressed by experts since the 1990s, Bahrain remains heavily reliant on the oil and gas sector.

Subsidies and Regulatory Frameworks

According to the studies on BIPV, BIWE and Sustainable Buildings in Bahrain, the main barrier to constructing sustainable buildings in the country is the lack

and “Solar Energy Proposed,” Bapco News, February 2011 in http://www.bapco.net/media/pdf/newsletter%20(10%20feb%202011).pdf

46. NOGA negotiations: Norton Rose International Legal Practice, *Renewable Energy in Bahrain,* January 2011, Andrew Reid, Staff Writer, “Wind Energy Plant is Planned for Bahrain,” *Gulf Jobs Market News*, Bahrain, November 23, 2010 available at http://news.gulfjobsmarket.com/wind-energy-plant-is-planned-for-bahrain-7861973-news and *Tehran Times*, November 24, 2010 in http://www.tehrantimes.com/economy. The results of wind assessment for this project, expected by end 2010, were not made public.

47. For BAPCO R&D policy in solar energy see “Bapco se lance dans le Solaire”, [OA LS, SOE] May 23rd 2010; for Bapco Heliocentris cooperation in *Innovation Germany,* the Newsletter of the German Center for Research and Innovation, New York. Issue 5, August 2010 available at http://www.germaninnovation.org/news-and-events/newsletters

of incentives. The high initial cost of photovoltaic modules or wind turbines, high cost of maintenance and low financial revenue from such projects in areas with developed electricity grid, together with the fact that the cost of one KWh of electricity (tariff) in Bahrain is only one US cent – while it is 11 US cent in UK and US, and 22 US cent in Japan – are major concurrent causes.[48]

All these barriers obviously raise the question of the role of regulations and policy frameworks in promoting investment in solar or wind power generation projects in general, and those integrated with construction in particular. In the survey conducted in Bahrain in 2007 to assess the main constraints to the deployment of RES technologies in the building sector – apart from the technological challenges mentioned earlier – policy makers, architects and contractors point to the low cost of electricity and the absence of strategic plans, regulations, legislation and incentives as the main reasons for not adopting BIPV or RES technologies in general. Moreover, policy-makers think that the absence of a legislative environmental taxation on electricity consumption makes it even harder to offer such incentives to investors or users alike.[49]

Nevertheless, whereas oil- and gas-generated electricity prices continue to be subsidized by Bahrain, in spite of facing rising fiscal deficits partially due to subsidies on power, water and fuel,[50] the government recognized the need to reduce domestic energy consumption for continued energy security. In May 2010, the Bahraini Minister for Housing announced a Green Buildings initiative for the country, stating that the development of an updated building code was also in progress. More recently, Bahrain's Ministry of Works has announced that green building specifications will be considered in government construction and that the Construction Projects Directorate has already applied these specifications in a number of schools currently under construction where environment-friendly materials are used in air channels to limit effect of greenhouse gases/global warming, and air conditioning and lighting systems are to be controlled to preserve energy.[51] Such steps could pave the way for better public awareness about energy conservation

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48. Alnaser, Flanagan, and Alnaser, "Model for Calculating the Sustainable Building Index (SBI)," 2037-2043.

49. Alnaser and Flanagan, "The Need for Sustainable Buildings Construction," 495-506, esp. 498.

50. Reuters, "Bahrain Plans to Use Nuclear Power by 2017," December 23, 2010.

51. Renewable Energy and Energy Efficiency website: http://www.reeep.org/index.php?id=9353&special=viewitem&cid=107 and statements of Mona Al Motawa, Construction Projects Director in the Ministry of Works, in "Bahrain to Adopt Green Building Specifications," *Khaleej Times,* June 29, 2011.

imperatives and associated environmental benefits. Yet, as the built environment (residential + commercial) in Bahrain accounts for more than 80 percent of the country's electricity consumption, such regulatory frameworks could be enlarged in order to integrate RE technologies in the end-use electricity consumption.

Overall, however, the Bahrain government's steps towards RES electricity production remain hesitant, for despite the multitude of initiatives and announcements made by major energy stakeholders over the last five years or so, there is no formal policy framework in place so far to support the development of large or small RE projects in the country.

Furthermore, the absence of policies and regulations in Bahrain, along with the failure to capitalize on earlier studies and research – as exemplified by the government's adoption of foreign turnkey projects – affects not only the potential of the local RES energy market but also diminishes confidence in the country's own experts and competencies. Together with shortage of skills and education, this sends the wrong signal for possible development of RES economies of scale in the country.

Strategic sustainability imperatives in Bahrain are huge; however, uncertain or contradictory policy statements concerning targets, priorities or strategies related to RES development do not serve to attract investments or spread awareness among the public as to the sustainability of such technologies in the country.

Chapter Two

Kuwait

Electricity and Water: Rapid Expansion and the Energy Efficiency Imperative

Demand for electricity and desalinated water is rapidly and continually increasing in Kuwait. As this desert state mainly depends on oil to produce these commodities,[1] mounting pressure to expand production is leading to increasing consumption of fossil fuels. In 2008 alone, the value of fuel supply to power plants approached $4.5 billion – at a subsidized $50/barrel to generate 52 TWh/year of electricity.[2]

Kuwait is the fourth largest oil exporter in the world, and most of its economy relies on the revenues from fossil resources. When one considers that the average monthly price of Kuwaiti oil export in 2008 was about $90.54/barrel,[3] one can easily see how domestic electricity demand puts a serious burden on the government budget.

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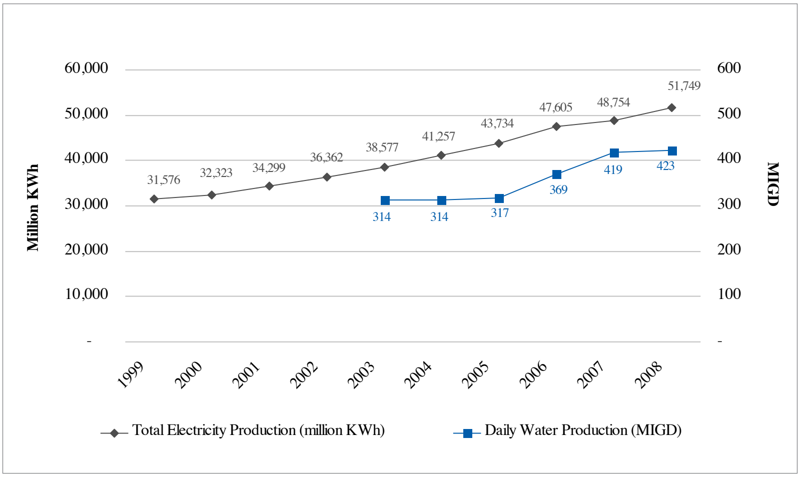
1. According to the Ministry of Electricity and Water (MEW), in 2008, the power sector consumed 72.181 million of Barrels of oil, in which gas oil, crude oil and heavy oil contributed 9.64 percent, 13.11 percent, and 77.25 percent, respectively; statistics on natural gas supply are not available. Source: Kuwait's MEW *Electrical Statistics, 2009*, 228.
2. Salem Al-Hajraf, "Why Clean Energy for Oil Countries" (Presentation given during the 1st Meeting of the Discussion Groups of the EU-GCC Clean Energy Network, Dubai November 30, 2010); electricity production figure from Kuwait MEW *Electrical Statistics, 2009*.
3. Philip M. Mobbs, "The Mineral Industry of Kuwait," *U.S. Geological Survey Minerals Yearbook -2008*, available at http://minerals.usgs.gov/minerals/pubs/country/2008/myb3-2008-ku.pdf

Growth in Electricity and Water Consumption - Kuwait



In the period from 2003 till 2008, the consumption of both electricity and water increased by 34%. In the next five years, the Ministry of Electricity and Water estimates that consumption will increase by 51% for electricity and 65% for water.
Source: Kuwait's Ministry of Electricity and Water

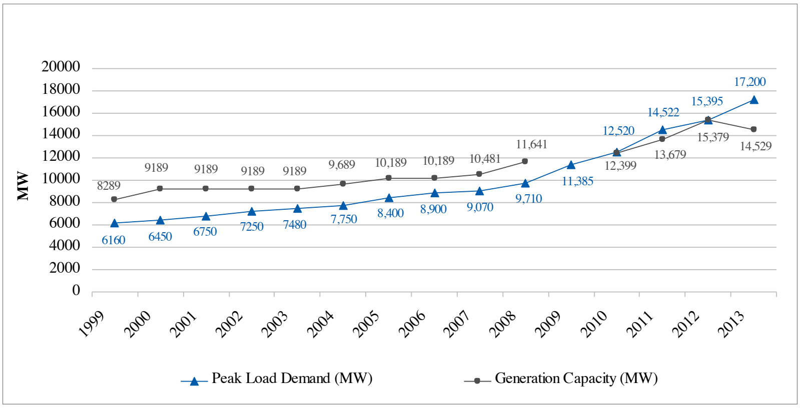
Kuwait had a power capacity of around 11,600 MW in 2008 and would need to double this figure by 2020.[4] Previously, due to increasing demand in the construction sector as well as in the residential and commercial sectors, electricity consumption grew at a rate of 7.25 percent annually between 1999 and 2009. For the last five years, peak demand has grown at an annual rate of 12 percent, but this was not matched with adequate new generation capacity, as a result of which the country experienced black-outs during summer.

With one of the world's highest per capita power consumption rates – 16.75MWh/capita in 2008[5] – and an average annual growth rate of electricity demand that will exceed eight percent for the next decade, it has become critical

4. Statistics for 2008, from Ministry of Electricity and Water *Electrical Statistics*, Chapter 2 available at http://www.mew.gov.kw/en/?com=category&id=80&act=view; projections (estimates) communicated by Suhaila Marafi, Director of Studies and Research at Kuwait's Ministry of Electricity and Water, in "Kuwait to Spend $27bn on Power Needs to Double Capacity by 2020," Reuters, March 28, 2011 available at http://www.emirates247.com/business/economy-finance/kuwait-to-spend-27bn-on-power-2011-03-28-1.373982; Figures of the real installed capacity differ from one source to another at about plus or minus 1,000 MW.
5. International Energy Agency, *2010 Key World Energy Statistics* (Paris, 2010), 53.

for Kuwait to accelerate the implementation of new power plants to cope with such rapid expansion of demand. For this, the country would eventually involve the private sector in building them.[6]

Kuwait - Electricity Capacity and Peak Load 1999 - 2013



In the past, Kuwait's electricity capacity exceeded peak load. The acceleration of demand within the last three years has created electricity shortages and black-outs.
Source:Based on Kuwait's Ministry of Electricity and Water Statistics and Projections

In fact, until recently all power plants in Kuwait were publicly funded,[7] except for the first independent power and water project (IWPP), a 1,500 MW plant at Al Zour that has engaged a private developer to build and operate it. However, despite the big potential of the power sector in Kuwait, political friction between the government and the National Assembly has hampered progress on many renovation and development projects over the past few years, and power plants are no exception. Hence, with the Ministry of Electricity and Water (MEW) projecting to expand installed capacity, the Al Zour IWPP will be seen as an important test case, not only for the financial, legal and technical aspects of foreign and/or private investment projects in Kuwait's fossil fuels-based electricity sector, but eventually for any future power projects that would use renewable energy technology to produce electricity.[8]

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6. Badr al-Shuraian, Minister of Electricity and Water, quoted in "Kuwait Eyes Increase in Water, Electricity Capacity," Bilateral US-Arab Chamber of Commerce Monthly Newsletter - April 2011 available at http://www.bilateralchamber.org/newsletter/2011/april/utilities.html
7. Ministry of Electricity and Water website, http://www.mew.gov.kw/en/
8. According to MEED, the Ministry of Electricity and Water intends to expand installed capacity to

Indeed, in its ambitious 2009 plan, the MEW also called for exploration of alternative energy sources for power generation; one of the considered options was renewable energy technologies. The ministry, which has the monopoly of the power supply in Kuwait, had then warned that, in addition to renovation and expansion of the whole national power system, the country had to invest in the rationalization of energy use in order to cover the rising demand and curb its annual growth rate.[9]

Kuwait is considered to be one of the countries with the least secure water resources in the world; about 95 percent of its reserves are produced out of seawater desalination conducted in five desalination plants. Paradoxically, the country's per capita water consumption is one of the highest in the world, reaching 37,707 imperial gallons in 2008. As this demand continues to grow, Kuwait is planning to spend about $21.3 billion on power and water projects in the framework of its 2010-2014 development plan. This will result in raising its desalination capacity from 423 million imperial gallons per day (MIGD) in 2008, to 600 and then 700 MIGD by 2014 and 2016, respectively.[10]

In Kuwait, it has been observed that water production and air conditioning – especially during the hot months – account for up to 70 percent of electricity consumption, which partly explains why the country has high power consumption rate per capita.[11] However, air-conditioning, which is responsible for extreme peak

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26GW by 2020, which is different from other projections. Other sources from the Kuwait MEW predict that Kuwait will boost power capacity to around 16 GW by 2012, or 23.2 GW by 2020; see notes 4 and 6; For more information on projects of the power sector in Kuwait see Digby Lidstone, "Testing the Appetite of Investors," *MEED Supplement on GCC Electricity*, 2010.

9. MEW also mentioned coal and nuclear energy as alternative future sources, in MEW *Electrical Statistics*, Chapter 1 available at: http://www.mew.gov.kw/media/Statistics/2009/electrical/Chapter%2001.pdf

10. Statistics for 2008, from Ministry of Electricity and Water *Electrical Statistics*, Chapter 2, available at http://www.mew.gov.kw/en/?com=category&id=80&act=view; water projections by Badr al-Shuraian, Minister of Electricity and Water, quoted in "Kuwait Eyes Increase in Water, Electricity Capacity," see note 6. Other sources put Kuwait's water capacity at 390 MGPD and its expansion schemes at 760 MGPD by 2020: Suhaila Marafi, Director of Studies and Research at Kuwait's Ministry of Electricity and Water, quoted in "Kuwait to Spend $27bn on Power Needs," see note 4.

11. When temperatures hit 48 degrees Celsius by the end of May 2011, power consumption level reached 9,850 MW and desalinated water production reached 407 MGPD while consumption reached approximately 393MGPD. See *Kuwait Times*, "Water Supply Adequate, Power Cuts Unlikely," June 1, 2011:http://www.kuwaittimes.net/read_news.php?newsid=NDIyNzQzNjcy. Also in Magazine of the Orient, http://www.zenithonline.de/deutsch/wirtschaft//artikel/alles-haengt-am-oel-001045/, January 2010.

loads in summer, is singularly the largest consumer of electricity. As the built environment accounts for a significant proportion of this consumption, implementing a strategy to optimize cooling systems' operation in Kuwait would minimize peak loads and consequently have a large impact on energy efficiency and saving.[12]

Similarly, a rational use of energy becomes imperative in all sectors; for instance, the processes of transforming thermal power (steam) to electricity in Kuwait's power plants are estimated to be only 35 percent efficient, which poses real energy efficiency issues as more than 60 percent of the thermal power generated from oil is wasted.[13]

Against this backdrop, the MEW has been planning to enhance the installed capacity of power stations and improve the efficiency of existing ones by adopting efficient power generation technology, namely combined cycle power generating systems for new installations or system upgrading, with the aim of reducing fuel consumption as well as greenhouse gas (GHG) emissions. For instance, Alstom has recently been awarded a contract to build a steam-tail add-on power plant for Kuwait's Az-zour gas-powered power plant which will result in adding steam power generation equipment to an existing gas power plant to increase its efficiency.[14]

Kuwait's power plants are mostly operated by fuel oil and crude, but the country increasingly requires supplies of gas for its electricity and desalinated water production, its enhanced oil recovery (EOR) operations, and to reduce domestic petroleum consumption that has been growing with the increased petroleum-fired electricity. However, demand for power has frequently outpaced gas production/supplies during the peak seasons resulting in the shutdown of refinery and petrochemical operations in order to meet the public's electricity needs.[15]

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12. Study developed by the Department of Building and Energy Technologies for the Kuwait Institute for Scientific Research (KISR) main building. See A. Hajiah, G. Maheshwari, A. El-Sherbini and R. Alasseri, "Optimization of Cooling Production in Kuwait Institute for Scientific Research Main Building," *KISR Scientific Report 2006-2008*, esp. p. 309 available at: http://www.kisr.edu.kw/Data/Site1/images/kisr_publications/978-999-06-95-05-2.pdf

13. Statement by Dr. Salem Al-Hajraf, in Hamad Al-Sayyed, "We Have Established 2 Wind Turbines, 6 more to Come: KISR Official," *Al Watan* Daily, June 23, 2010.

14. The steam-tail will add 400 megawatts (MW) to the existing 800 MW power plant capacity and cut emissions per MW produced. See "Alstom Transforms Kuwait's Gas Powered Unit Az-zour into a Combined-cycle Power Plant," March 28, 2011 http://www.alstom.com/power/news-and-events/press-releases/alstom-transforms-kuwaits-gas-powered-unit-az-zour-into-a-combined-cycle-power-plant/

15. US Energy Information Administration, Kuwait Analysis Brief, available at: http://www.eia.gov/countries/cab.cfm?fips=KU

Hence, if Kuwait wants to conserve oil or gas for economic or logistical reasons, integration of RES into its energy mix should be pursued. In particular, solar thermal technologies could be incorporated into electricity generation plants using combined-cycle technology (fed by fossil fuels) to tackle the intermittency issues. As Kuwait is planning a total of 3,700MW of power – in Shuaiba South and Doha East – that will be generated by steam turbines,[16] technical feasibility of hybrid solar/fossil-fuel combined cycle facilities can help the country reach its recently announced target of 10 percent of sustainable sources in its energy mix by 2020.[17]

Furthermore, consistent with all predictions, the cost of electricity production from fossil fuel sources will increase substantially in the future.[18] So, in addition to diversifying energy resources with the integration of sustainable energy technologies, Kuwait will have to re-think its energy subsidies, which actually are the highest in the region and beyond. Indeed, as per 2010 prices, electricity tariffs in Kuwait varied from 1 to 10 fils (USD cent 0.36 to USD Cent 3.6) per KWh, whereas the actual production cost is 35 fils per KWh.[19] Such low prices surely explain the wasteful patterns of consumption in both the electricity and water systems; they may also be responsible for procrastination in renewable energy deployment in Kuwait.[20]

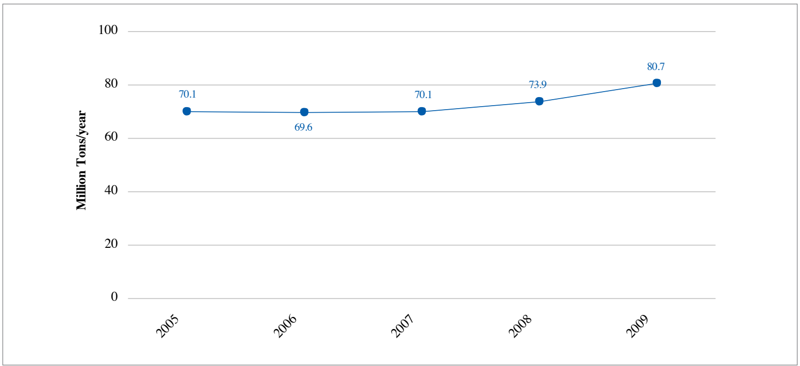
Energy Conservation and Environmental Measures

Kuwait's only resources of primary energy are oil and natural gas, which are non-renewable and lead to the generation of greenhouse gases (GHGs). In 2008, local energy consumption, excluding feedstock for refineries, was estimated at around 15 percent of production.[21] In addition to the growing financial cost of fossil

16. Ibid., citing the Ministry of Electricity and Water, *MEES* and *MEED*; 10.
17. "Kuwait Raises the Bar on Clean Energy in Gulf," *Bloomberg* October 26, 2011; available at: http://www.arabianbusiness.com/kuwait-raises-bar-on-clean-energy-in-gulf--427128.html
18. In 2005, the total cost of kWh from gas was US¢ 3.35 and it will be nearly doubled to US¢ 6.29 if it is gas-based and threefold to US¢ 9.02 if it is oil-based, by 2015; in W.E. Alnaser and N.W. Alnaser, "Solar and Wind Energy Potential in GCC Countries and Some Related Projects," *Journal of Renewable and Sustainable Energy* 1 (2009).
19. Eyad Ali al-Falah, assistant undersecretary for technical services at the Ministry of Electricity and Water, to Bloomberg, October 26 2011.
20. In 2010, the Kuwaiti authorities recognized the wasteful patterns of consumption in both the electricity and water systems, and it was announced that these tariffs would increase by 15 to 150 percent depending on the type of consumer; in "Kuwait Government Eyes Hike in Prices of Electricity & Water," Zawya, April 30, 2010.
21. Kuwait Institute for Scientific Research, *KISR Scientific Report 2006-2008*, vii.

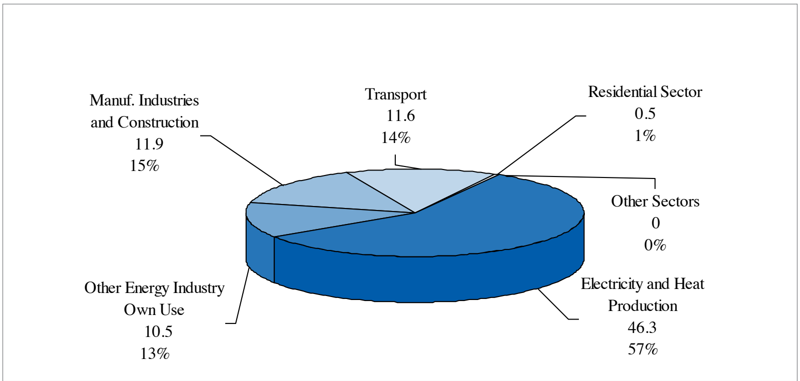
fuels fired to generate electricity, the negative environmental impact of these sources of energy is increasing; carbon emissions in Kuwait grew by an average of 5.3 percent between 2006 and 2009; they reached 25.5 tons per capita in 2008 which is among the third highest rates globally, after Qatar and the United Arab Emirates (UAE).[22]

Kuwait CO_2 Emissions 2005 - 2009



Source: Based on IEA, *CO_2 Highlights* (2011)

Kuwait CO_2 Emissions from Fuel Combustion in 2009 by Sector (million tons)



Growth of CO_2 emissions has accelerated in the last 3 years. More than half of Kuwait's CO_2 emissions from fuel combustion originates from electricity and heat production. Source: Based on IEA, *CO_2 Highlights* (2011)

22. International Energy Agency, *2010 Key World Energy Statistics*.

Domestic oil consumption has been steadily rising at an average growth rate of five percent yearly from 2005 to 2010, when it reached 413,000 barrels a day.[23] This is mainly due to increasing petroleum-based electricity generation that, according to MEW statistics, claimed the burning of 72.2 million barrels of oil equivalent in 2008, 90.3 percent of which was heavy and crude oil.[24] The same year, Kuwait's total primary energy supply (TPES) reached around 192 million barrels of oil equivalent;[25] this shows the important share of electricity generation in the total national energy demand of Kuwait.

Obviously, the rising electricity consumption and associated environment risks call for the integration of clean technologies in general and the development of RES in particular.

The ratification of the Kyoto Protocol by Kuwait in March 2005 permitted rethinking of the energy policy in accordance with certain terms of the climate change agreement. Following this, alternative energy has reemerged as an important field of research that tends to be promoted by national authorities and institutions. Increased competitiveness of some renewable energy technologies as compared to fossil fuels and the rising costs of the latter have prompted Kuwait to express interest in the solar and wind energy sources. However, prospects of RE development in the country could be affected by conservation policies and other environmental measures.[26] So far, Carbon Capture and Sequestration (CCS) technologies have the preference of the country's hydrocarbons sector which sees them as the most efficient way to comply with the Kyoto conditions, as compared to creating a whole new energy system (solar or wind) that remains costly and would lack profitability in the short term.

For instance, the industrial component of the Environmental Monitoring Information System of Kuwait (eMISK-Industry) is expected to estimate and quantify the annual pollution loads emitted by the different industrial facilities through inspection and environmental monitoring of the industrial facilities and, thereby, permit the drawing up of scenarios and action plans by policy-makers to

23. *BP Statistical Review Report 2011*.

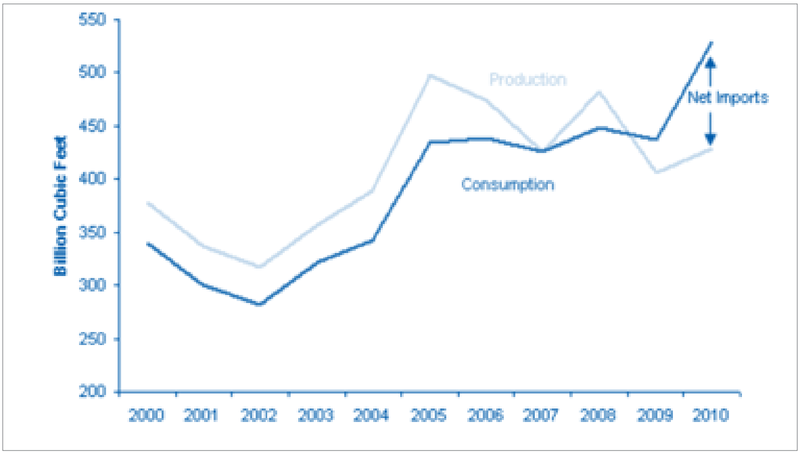
24. The number of barrels of oil equivalent consumed daily to generate electricity in Kuwait increased by 2.9 percent annually between 2005 and 2008; calculations based on Kuwait's Ministry of Electricity and Water *Electrical Statistics, 2009,* 228.

25. TPES figure for 2008 from International Energy Agency, *2010 World Key Energy Statistics*.

26. See, for example, KPC CEO Speech in MEED 6th Annual Kuwait Projects Conference, November 29-30, 2010; available at: http://www.kpc.com.kw/MediaCentre/Speeches/AllSpeeches/29111011.aspx

reduce pollutants emission in Kuwait.[27] Such action plans could include enhanced oil recovery (EOR) using CCS. By collecting and injecting carbon dioxide to increase the productivity of reservoirs of the old oilfields, Kuwait plans both to protect the environment and divert natural gas that it currently injects into those reservoirs, from its oilfields to its power stations. [28]

Kuwait's Natural Gas Production and Consumption 2000 - 2010*



In the past two years, Kuwait has become a net importer of gas due to the combination of an increase in consumption and a decrease in production.
* Estimates
Source: Energy Information Adminstration

Indeed, the country has recently become a net importer of natural gas, which is driving the focus on exploration.[29] However, gas shortages should also motivate rational use of energy and the promotion of alternatives resources in order to mitigate imports and the exceptionally high costs of exploration in Kuwait.

Through an energy conservation paradigm, Kuwait should thus consider using

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27. (eMISK) is a four-pronged system initiated by the Environmental Public Authority (EPA) of Kuwait to protect the environment in Kuwait and tackle related issues; more information on http://www.epa.org.kw, http://www.emisk.org/emisk/Default.aspx and http://www.emisk.org/emisk/ProjectOverview.aspx?prj=2
28. For more information on Kuwait EOR projects, see Tamsin Carlisle, "Kuwait, Japan Team up To Tackle Carbon Capture," in CO_2-Norway available at: http://www.co2.no/default.asp?Uid=224&Cid=31
29. US Energy Information Administration, *Kuwait Analysis Brief*.

steam injection to increase the production of its old reservoirs. To this end, EOR techniques can deploy solar thermal energy for steam generation, a technology Chevron started using in California and is considering applying in the Wafra heavy oil field.[30]

Potential of Renewable Energy Sources (RES)

Kuwait is located at 29°30' northern latitude and 45°45' Eastern longitude. Its total area is 17,820 km^2 and most of its lands are desert. The climate is characterized by a long, dry, hot summer with temperatures reaching 50°C and frequent sandstorms, and a cooler winter with temperatures falling below 4°C.[31] High levels of solar radiation and sunshine duration were registered in Kuwait, which provides the country with enormous amounts of solar energy and good potential for solar-based generation of electricity.

Kuwaiti and foreign institutions conducted several studies on Renewable Energy Sources (RES) – mainly solar and wind – to explore their potential and possible applications in the local context. According to a German Aerospace Center study, Kuwait has among the highest performance indicators in terms of its Direct Normal Irradiance (DNI) – suitable for Concentrating Solar Power – and an equally high Global Horizontal Irradiance (GHI) – useful for photovoltaic systems; these amount to 2,100KWh/m2/year and 1,900 KWh/m2/year, respectively.[32]

Concentrating Solar Power (CSP)

High solar DNI and the average high ambient temperatures, in particular, make Kuwait's long summer period (approximately eight months) particularly appropriate for the deployment of CSP technologies as they would enhance the technical potential of such systems. Determined on the basis of both the performance indicators and the land resources that allow for the placement of CSP plants, the economic potential of this technology – in spite of the limited amount of lands

30. It is reported that a full field steam injection program is scheduled in Kuwait for 2014, with first application for late 2017, in Nick Wilson, "MENA Turns to Solar Power for EOR as Well as National Grids," mees.com, November 7, 2011.

31. Karen Frenken (ed.), *Irrigation in the Middle East Region in Figures*, AQUASTAT Survey – 2008, FAO Land and Water Division (2008); Kuwait Chapter, 251-262.

32. German Aerospace Center (DLR), *Concentrating Solar Power for the Mediterranean Region,* Institute of Technical Thermodynamics, Section Systems and Technology Assessment (2005), 55-62.

available for large-scale solar systems in Kuwait – was found to be 1,525 TWh/y. For comparison, the electricity consumption in Kuwait reached 51.75 TWh in 2008, or merely 3.4 percent of the country's CSP potential.[33]

Photovoltaic Energy

Analyzing weather data collected by the Kuwait Institute for Scientific Research (KISR) for 20 years, a study was conducted by the College of Technological Studies to find the hourly insolation on differently tilted surfaces for each month of the year. The study found that there is great solar radiation potential as the number of sunshine hours per day is large, especially during the period from May to September. Furthermore, it was observed that the maximum solar radiation and maximum electricity load in Kuwait occur at the same time of the year, which encourages the use of photovoltaic energy for electricity generation.[34]

However, it must be noted that harsh weather conditions in Kuwait could negatively affect the performance of photovoltaic cells. Despite the high rate of solar incident radiation, humidity and dust – due to frequent sandstorms – lead to the formation of a layer of crust on the surface of the solar panels which can reduce their effectiveness, hence making the regular cleaning of the panels necessary. Similarly, the space constraint could also affect the economic potential for PV plants. At any rate, based on the yearly average GHI in Kuwait and general PV growth rates, DLR calculations give 2.5 TWh/y only for PV economic potential in the country.[35]

Nevertheless, this space constraint could be compensated by integrating solar technologies into buildings' roofs and structures. Indeed, the Building Integrated Photovoltaics (BIPV) option represents a valuable opportunity for PV deployment in a relatively small country like Kuwait.

In a study exploring the potential of Photovoltaic system to reduce the electricity consumption in the residential sector, it was confirmed that the high levels of insolation combined with the high percentages of sunshine hours provide good conditions for the generation of PV solar electricity in Kuwait. In particular, analyzing 25 sampled houses, computer simulation was used to calculate the electrical generation from PV panels installed in the available built surfaces. Accordingly, it was concluded that:

33. German Aerospace Center (DLR), Concentrating Solar Power, and MEW statistics.

34. Ahmad Y. Al-Hasan "Electricity Generation Cost between Proposed Photovoltaic Station and Conventional Units in Kuwait," *Renewable Energy* 12, no. 3 (1997): 291-301.

35. German Aerospace Center (DLR), *Concentrating Solar Power*, 56.

> "When PV modules completely cover the entire surfaces of an "average" residential house in Kuwait, they will produce an annual amount of electricity of 148,039 kWhr/yr (65,890kWhr/yr from the roof, 10,668kWhr/yr from the North, 20,871kWhr/yr from the East, 28,244kWhr/yr from the South, 22,365kWhr/yr from the West), [but] if the building is oriented toward SE-NW axis the total electricity generated would increase to 157,792kWhr/yr. The average electricity production of the two orientations is 153,000kWhr/yr." [36]

This figure was found to be higher than the average house consumption of 128,000kWh/y in Kuwait, representing a surplus of 25,000kWh/y over the annual electricity need, which demonstrates the feasibility of green and energy-exporting architecture in Kuwait. But, even when PV modules are located on the roof only, for example, as shading devices with appropriate tilt angles, it was found that the electricity generated from the roof PVs can provide 50 percent of the electricity needed for 52 percent of the sampled houses. [37] This result confirms the fact that BIPV can definitely mitigate – at least by a ratio of 25 percent – the electricity consumption in the residential sector; the potential of energy saving will be even bigger when such green designs are coupled with conservation measures.

Wind Energy

Wind energy in Kuwait was also assessed and the annual electricity yield from wind power was found to be around 1605 of annual full load hours (capacity factor); this is considered to be economically viable, as it is superior to 1400h/y equivalent to a capacity factor of 16 percent, taken as the threshold of long-term economic potential.[38]

In 2006, the Department of Coasts and Air Pollution of KISR conducted a project to examine the characteristics, potential and applicability of wind energy in several inland flat desert areas of Kuwait, such as Al-Wafra and Al Taweel. According to the study, the annual average wind speed for the considered sites ranged from 3.7 to 5.5 m/s at the standard height of 10m and the corresponding annual wind power density (WPD) varied from 80 to 167 W/m^2. The annual WPD at 30 m height was estimated by extrapolation from the 10m height data and found to be varying between 130 and 275 W/m^2 in the open flat desert areas of the

36. Adil Al-Mumin and Abdullah Al-Mohaisen, "Greening the Kuwaiti Houses." (2006).
37. Ibid.
38. Number of hours of full load of wind in GCC countries from DLR study, *Concentrating Solar Power*, 57. No technical or economic wind energy potential was determined for Kuwait in this study.

northwestern and southern parts of the country. Monthly variation analysis shows high WPD during the high electricity demand summer season with maximum WPD of 555 W/m^2 at Al-Wafra in June. The study concluded that Kuwait has a great potential of harnessing wind energy for domestic and industrial use and that large-scale wind system implementation will lead to reduction in demand for new conventional power plants.[39]

More importantly, the wind electricity generation cost at Al-Wafra and Al-Taweel sites was found to be 33.7 fils/kWh and 35.8 fils/kWh, respectively; these figures, the study shows, are lower than the costs of conventional electricity generation at 36.4 fils/kWh, based on the then oil price of $50/bbl. As the fuel price accounts for 80 percent of the total production cost of conventional electricity production, any increase in fuel price would make wind energy more attractive, the study concludes.[40]

Research and Development (R&D)

Studies and Demonstration Projects

In the late 1970s and early 1980s, KISR, among whose primary objectives is the study of natural resources like energy and water and the means for exploiting them, focused significant attention on research and development (R&D) relating to renewable energy, primarily solar and wind, in order to help reduce fuel demand and provide supplementary sources of energy.[41]

KISR supervised and financed fundamental and applied research on solar energy systems and their technical feasibility for the country for power generation, heating and cooling purposes as well as water desalination. Such activities expanded to more than 140 research projects worth around $50 million and involving more than 70 researchers, engineers and technicians.[42] Studies and demonstration projects included:[43]

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39. Cost analysis was conducted for two different wind turbine models, Nordex N60 and Vestas V52, with hub height of 69m and 65m, respectively; W. Al-Nassar, S. Alhajraf, A. Al-Enizi and L. Al-Awadhi, “Potential Wind Power Generation in the State of Kuwait,” *Renewable Energy* 30, no. 14 (November 2005): 2149-2161.

40. Ibid.

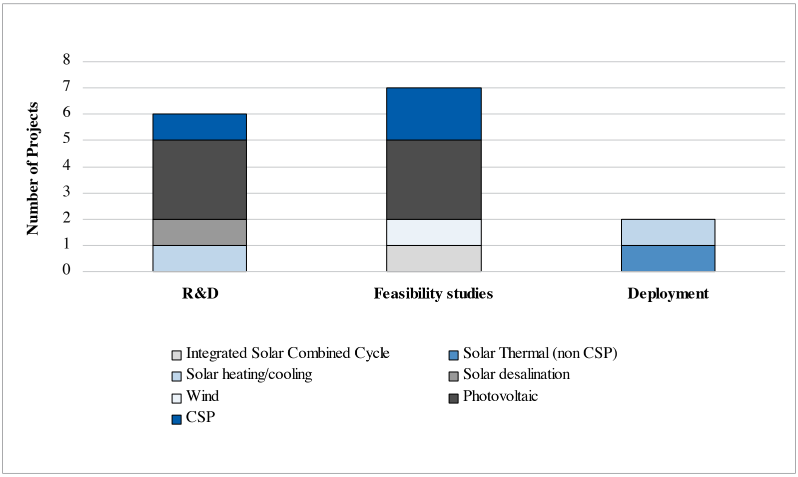
41. Biomass and geothermal/hydropower are not being considered, although some experiments in hydroponics have been successful meaning the potential for future development (in Biomass energy) is present.

42. Al Naser and Al Naser, “Solar and Wind Energy Potential in GCC Countries.”

43. Salem Al-Hajraf, “Why Clean Energy for Oil Countries.”

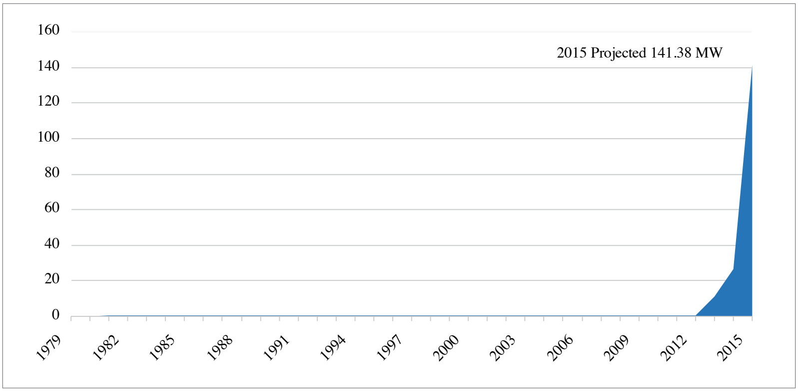
- 100 kW Solar Thermal Power Station (1979 - 1984)
- PV system for agriculture green houses (1982)
- Solar desalination system (1983)
- PV system at Kuwait English School (1984)
- Solar cooling system at Ministry building (1986)

Number of Renewable Energy Projects in Kuwait per Nature and Technology (up to 2015)



Source: Author's calculation

RES Projects Kuwait - Cumulative Capacity (MW)



Since the first R&D projects in 1979, no RES deployment has happened in Kuwait.
Source: Author's calculation

Unfortunately, KISR RE research projects were discontinued in 1986 without having any impact on the country's electricity generation sector. Lack of technical and economic viability of many projects and uncertainties about the durability of the designs have reduced prospects of implementation of RE technologies. In KISR experts' view, "the technology was not cost effective" and, curiously, did not "serve strategic interests of the country."[44]

However, in the year 2000, the research institute renewed its interest in solar and wind technologies. For instance, in 2006, the Department of Water Technologies conducted a review of solar desalination technology, its status in the Gulf region in general and in Kuwait in particular, and its outlook for the future; the Department of Coast and Air Pollution investigated the potential of wind power generation in Kuwait, identified the most performing potential wind farms and conducted a cost analysis of two different wind turbines models (study cited earlier in the section on "wind potential"); the Department of Building and Energy Technologies carried out different studies on "Experimental Wind Power Stations in the State of Kuwait," "Kuwait's Solar Radiation for Photovoltaic Applications," and "Application of Green Building System in Kuwait"; the Department of Advanced Systems studied the "Integration of Distributed Energy Resource with Electric Utility Network" and its technical and regulatory challenges.[45]

Cost of Renewable Energy

During the 1990s, a comprehensive analysis was conducted by the College of Technological Studies to evaluate the cost of kWh generated from a (hypothetical) photovoltaic station located in Kuwait and to compare it with the cost of a kWh generated from conventional (steam and gas) units in the country. The study concluded that to be competitive with the cost of KWh generated in Kuwait from steam turbines ($0.131) or the cost of KWh produced from gas turbines ($0.108) during the peak hours, the capital cost per installed PV watt should not exceed $5, which was not the case at that time. It should be noted that the fuel cost which served as a basis for these calculations was then $20/bbl. [46]

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44. Kuwait Institute for Scientific Research (KISR), *Scientific Report 2006-2008*, p.vii.

45. No major projects have yet commenced, including the announced construction of a 1MW wind power station and the fabrication of integrated PV systems. KISR *Scientific Report 2006-2008*, 157-8; 328-9, 258-9; 355-6.

46. A. Hasan and A.A.M. Sayigh, "Cost and Sensitivity Analysis for Photovoltaic Station in Kuwait," *Renewable Energy* 8, no. 1-4, (May-August 1996): 420-423 ; Al-Hasan, "Electricity Generation Cost."

In 2010, however, a KISR study showed that when the cost of oil is around \$100/barrel and the PV system efficiency around 15 percent, the levelized cost of electricity (LCOE) of a 1 MW station is estimated to be around \$0.20/kWh. Furthermore, the true economic cost of LCOE of a PV system is found to decline significantly (to \$0.17 - 0.05 /KWh) when one takes into account the value of the saved fossil fuels used in producing traditional electricity (\$0.09/KWh) and the cost of related CO_2 emissions (\$0.02/KWh) that have been subsequently lowered.[47]

Grid-connected Renewable Energy

Other studies have also been carried out to assess the technical and economic feasibility of grid-connected photovoltaic systems in the Kuwaiti climate.

In particular, one of the studies examined the cost-effectiveness of solar modules mounted on building roofs that already receive electricity from the grid in light of the electricity tariffs used in Kuwait. Taking into account the electrical load of the building and the optimum orientation (latitude) of the PV arrays, it was found that the energy production from a 20 KW PV array satisfies about 70 percent of the total building load, which saves \$1625 over the 10 months of simulation.[48]

More generally, the main findings of the research on grid-connected RE sources units in Kuwait can be summarized as follows:

- A significant reduction in peak load can be achieved with grid-connected PV systems, as the peak load matches the maximum incident solar radiation in Kuwait[49]
- Basic RES systems (units) can be operated either in normal interconnected mode and islanded mode to inject power to a regional grid to enhance local reliability
- For Kuwait vertically integrated electric power stations (utilities), anticipated challenges and concerns of grid-connected RES units can be managed through local autonomous supervisory controllers to ensure that the RES' power output is quantitatively and qualitatively compatible with the regional or national grid's

47. Mohammad Ramadhan and Adel Naseeb, "The Cost Benefit Analysis of Implementing Photovoltaic Solar System in the State of Kuwait," *Renewable Energy* 36, no. 4 (April 2011): 1272-1276.
48. Ali H. Abdullah, Adel A. Ghoneim and Ahmad Y. Al-Hasan, "Assessment of Grid-connected Photovoltaic Systems in the Kuwaiti Climate," *Renewable Energy* 26, no. 2 (June 2002): 189-199.
49. A. Y. Al-Hasan, A. A. Ghoneim and A. H. Abdullah, "Optimizing Electrical Load Pattern in Kuwait Using Grid Connected Photovoltaic Systems," *Energy Conversion and Management* 45, no. 4 (March 2004): 483-494.

power (accumulated electric capacity of such RES units should then range from 10 to 500MW or 1 GW to several GW for Medium Voltage or High Voltage networks, respectively)[50]

- Introducing RES units in a vertically regulated power system encourages the liberation of power which supports the sustainability of energy supply in Kuwait.[51]

It is argued, however, that for small volumes and remote locations the likely mismatch between the location of the electric grid and the end users may be a limiting factor for in grid RE transmission schemes.[52]

Policies and Future Deployments

Targets

Although Kuwait has demonstrated interest in the application of renewable technologies since the late 1970s, and despite extensive research conducted subsequently to assess RE potential in the country, apart from Research and Demonstration projects no large deployment was championed, and the current RES installed capacity in Kuwait does not exceed 400KW, compared to hydrocarbons based power capacity of 13.6 GW in 2011.

Kuwait seems to be committed to doing something about its future energy mix though. In October 2009, the country announced that it aims to produce five percent of its electricity from renewable sources by 2020. According to some projections, the total power generation for the year 2020 will reach 23 GW; thus, RE installed capacity is supposed to reach 1,150 MW to meet the target announced recently by the authorities. This would require huge investments and a large number of stakeholders to be involved. Indeed, challenges will encompass not only project development complexities; legislative, financial, and socio-economic measures will also need to be devised and implemented in order to ensure the wide adoption of RE technologies.

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50. O. Alsayegh, S. Alhajraf and H. Albusairi, "Managing Grid-Connected Renewable Energy Sources Systems," in GCREEDER 2009, Amman-Jordan, March 31- April 2, 2009, also available in *Energy Conversion and Management* 51, no. 8 (August 2010): 1690-1693.

51. Ibid.

52. Saad Al-Jandal, "Gulf Clean Energy Prospective and the Role of Renewable Resources" (Presentation to the EU-GCC Clean Energy Network 1st Meeting of the Discussion Groups, Dubai, November 30-December 1, 2010).

At the same time, ever growing energy demands on the one hand and pressures for a continuous supply on the other are pushing for an alternative that is as "secure" as the burning of oil to generate electricity. Two years ago, nuclear energy seemed to be a favored option for achieving all these objectives in addition to the protection of the environment as a bonus because it is considered a clean energy. In 2009, Kuwait established the National Nuclear Energy Committee (KNNEC) to consider the development of four nuclear plants with a capacity of one GW each.[53] In 2011, however, triggered by other environmental risks, Kuwait retracted from pursuing nuclear power as part of the country's energy mix and the government disbanded KNNEC; the nuclear program has been reduced to research and training components under the responsibility of KISR.[54] Curiously enough, almost in parallel to this decision, a MEW official announced that the country aims to generate 10 percent of its electricity from sustainable sources by 2020. [55] It was not specified whether this meant RES exclusively, but such target would be too high for the time limit.

All the same, many different solar and wind deployment plans have been unveiled recently with the perspective of deploying up to 1,000MW in the future, which suggests that Kuwait is moving ahead towards its RE projections. Namely, in addition to previous plans to deploy a combined solar and gas steam generation facility (discussed later), a 70MW renewable electricity complex is expected to be set up by MWE at Abdeli, near the Iraqi border, and will be connected to the grid. It should comprise a 10MW photovoltaic solar plant, a 10MW wind farm and 50MW CSP facility using trough technology. [56]

53. KPC CEO Speech in MEED 6th Annual Kuwait Projects Conference, November 29-30, 2010; and V. Ratcliffe, "Kuwait Moves Ahead with Nuclear Plan," *MEED*, December 2010, available at: http://www.meed.com/sectors/power/nuclear/kuwait-moves-ahead-with-nuclear-plan/3080663.article ; Kuwait signed cooperation agreements with France, the US and Japan in 2010, and hired two consultants to study the potential of six sites to host nuclear power projects: *MEED*, "Diversifying Energy Mix in Kuwait," December 2010, available at: http://www.meed.com/sectors/power/nuclear/diversifying-energy-mix-in-kuwait/3080666.article

54. V. Ratcliffe, "Doubt Cast at Kuwait's Nuclear Plans," *MEED*, July 13, 2011, available at http://www.meed.com/sectors/power/nuclear/doubt-cast-over-kuwaits-nuclear-plans/3103966.article and V. Ratcliffe: "Kuwait Disbands Nuclear Body," *MEED*, November 10, 2011 available at: http://www.meed.com/sectors/power/kuwait-disbands-nuclear-body/3114815.article

55. Statement by Eyad Ali Al-Falah, assistant undersecretary for technical services and the MEW's alternative energy coordinator at the Ministry of Electricity and Water, in "Kuwait to Harness Renewable Energy," *Saudi Gazette*, October 27, 2011 available at: http://www.gulfinthemedia.com/index.php?m=economics&id=578334&lim=60&lang=en&tblpost=2011_10

56. "Kuwait to Harness Renewable Energy," and V. Ratcliffe, "Kuwait Plans Renewable Energy

Renewable Energy in the Oil Sector

The most important rationale for adopting alternative sources of energy in Kuwait seems to be linked to conservation of fossil fuels and optimization of oil exports. Hence, amid serious concerns about the country's mounting energy consumption and its financial and environmental price, Kuwait Petroleum Corporation (KPC), which manages domestic and foreign oil investments, started looking at the possibilities of using solar power in its sector beginning 2008. Its Research & Technology Department organized workshops to review "New Energy Technologies" and explore "Renewable Energy Applications in the Oil Sector." The workshop on renewable energy applications was organized in cooperation with KISR, Kuwait Foundation for the Advancement of Science (KFAS), Kuwait University and Kuwait Oil Company (KOC) and addressed solar energy in Kuwait, fuel cells used in desalination, methods of using renewable energy technologies in KOC activities, as well as future applications of renewable energy technologies.[57]

In fact, KPC interest in these technologies has expressed itself through the private equity sector. Following a surge in oil prices in the mid 2000s, KPC established in 2006 a $100 million venture capital fund focused on Renewable Energy technologies (RET).[58] More recently, the move towards RES applications has been underlined in speeches by KPC's CEO during 2010 and early 2011, wherein it was stated that KPC's commitment to protect Kuwait's environment and conserve conventional resources should also take advantage of RES technologies.[59]

In this context, KOC, the upstream subsidiary of KPC, is considering the use of solar energy as an alternative to oil to produce energy. It was recently announced that KOC will launch tenders for two pilot solar-power schemes, in the first quarter of 2012; the first would be for the construction of a five MW photovoltaic power

Complex," *MEED*, November 10, 2011; available at: http://www.meed.com/sectors/power/renewable-energy/kuwait-plans-renewable-energy-complex/3114817.article

57. KPC Reviews New Technologies," July 7, 2008; available at: http://www.kpc.com.kw/mediacentre/enews/31/new.html ; and "Research and Development Organizes a Lecture on Renewable Energy," March 21, 2010; available at: http://www.kpc.com.kw/MediaCentre/ActivitiesEvents/wpp/Research%20and%20Development%20%20Organizes%20a%20Lecture%20on%20Renewable%20Energy.aspx

58. Global Investment House, "MENA Private Equity," July 2007, available at: http://www.globalinv.net/research/Private-Equity-Strategy-072007.pdf

59. "KPC CEO Address on the Occasion of the New Year," January 2011, available at: http://www.kpc.com.kw/MediaCentre/media/CEO_Address_2011.aspx

plant, and the second for the integration of a CSP plant to produce steam for enhanced oil recovery (EOR).[60]

Potential of Thermal Solar Power

In 2008, the Ministry of Economy, Trade and Industry of Kuwait commissioned Japan External Trade Organization (JETRO) to prepare a feasibility study to assess the technical, economic and operational aspects of a large-scale Integrated Solar Combined Cycle (ISCC) power plant utilizing solar thermal energy to generate electricity. Average Direct Normal Irradiation (DNI) in Al-Abadilya, the chosen site of the project, was found to be 2,033 KWh/m^2/yr which confirmed the suitability of the site for use of CSP technology.

Accordingly, the planned ISCC plant, whose total nominal capacity would be 280MW, will comprise a power plant composed of 54 solar trough collectors that should generate a maximum 60 MW of power coupled with a Combined Cycle gas turbines-island to generate the remaining 220 MW.

It is argued that the performance of such a plant would be much higher than that of a conventional solar thermal power generation plant and a conventional combined cycle power plant mounted separately.

As much as the ISCC technology enhances efficiency by reducing energy waste it reduces CO_2 emissions during the power generation process; thus, it is an effective measure to cope with the increasing power demand while reducing greenhouse gas emissions.

Back in 2008, it was recommended that, if the project was implemented, further detailed studies should be executed and an Independent Power Producer (IPP) body established to regulate IPP business and encourage foreign investments in such projects in Kuwait.[61]

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60. Adel Mirza, "Kuwait Plans Pilot Solar Schemes", *MEED,* November 24, 2011, available at: http://www.meed.com/sectors/oil-and-gas/oil-upstream/kuwait-plans-pilot-solar-schemes/3117264.article

61. The planned ISCC power plant should be built on a BOOT (build, own, operate and transfer) basis of 25 years duration by an Independent Power Producer (IPP) with a customized Power Purchase Agreement (PPA); see Japan External Trade Organization (JETRO), "Study on Application of Integrated Solar Combined Cycle ISCC in Power Generation System in Kuwait," Summary of reports. January 2008. Kuwait was expected to invite bids in July 2011 for the construction of the ISCC plant; however, the project was delayed to March 2012 because the original site was considered unsuitable; besides, the total electricity capacity would be 228 MW, of which 65MW will be solar and the remaining gas-fired. Although tenders have yet to be awarded and a completion date is uncertain, Toyota Tsusho is considered the favorite to build this plant in

Prospects of Energy Conservation in Buildings

Given the high electricity consumption in the Kuwaiti residences, studies have investigated occupants' activity patterns in an attempt to explain the causes; they confirmed wasteful behavior that, in fact, would raise by 21 percent the annual electricity consumption predictions in this sector. The study showed that altering the occupants' habit in terms of switching the lights off whenever they leave the rooms and setting the A/C thermostat to 24°C instead of 22ºC will lead to annual savings of KD 170 million (this number was based on an annual reduction of 49,615 kWh calculated in the study multiplied by the 2003 electricity production rate of KD 0.014/kWh and by 250,000, which was the total number of housing units existing in Kuwait). [62]

The MEW has repeatedly called for an efficient use of energy;[63] however, since 2003, studies have recommended that the ministry' strategies, in addition to informative campaigns about the real cost of electricity or the money that can be saved from of its rational use, should be supported by increasing the electricity rates to at least the actual cost prices. Only then will the government see a change in the attitude towards energy conservation among the occupants' of Kuwaiti residences, as the study found no reasons to explain the wasteful patterns of consumption other than the fact that electricity is very cheap due to heavy government subsidy.[64] However, Kuwait still subsidizes electricity prices for more than 3.5 million residents (citizens and expatriates), where the KWh costs 2 fils (7 US cents), whereas it is produced at more than 35 fils.[65] When one considers that at least 50 percent of the total electricity generation is consumed by the residential sector,[66] one can clearly see how such tariff is not favorable for the rational use of energy.

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partnership with the MEW. See Bloomberg: http://www.bloomberg.com/news/2010-11-29/kuwait-to-spend-21-billion-on-power-water-projects-update1-.html, *MEED*: http://www.meed.com/sectors/power/renewable-energy/kuwait-to-build-solar-and-gas-hybrid-plant/3090527.article. The IPP scheme will be overseen by the Kuwait's Partnership Technical Bureau (http://www.ptb.gov.kw/en/projects.php)

62. A. Al-mumin, O. Khattab and G. Sridhar, "Occupants' Behavior and Activity Patterns Influencing the Energy Consumption in the Kuwaiti Residences," *Energy and Buildings* 35 (2003): 549-559.

63. Kuwait News Agency, "Kuwait Says Seek More Efficient Energy for All," June 22, 2011.

64. Al-mumin, Khattab and Sridhar, "Occupants' Behavior and Activity Patterns."

65. Eyad Ali Al-Falah quoted in "Kuwait to Harness Renewable Energy," see note 55. For more information on electricity and water tariffs in Kuwait, see the MEW website: http://www.mew.gov.kw/en/?com=content&id=93&act=view

66. Al-Mumin and Al-Mohaisen, "Greening the Kuwaiti Houses."

Similarly, incompatibility between architectural design and the Kuwaiti climate was found responsible for the energy "unconsciousness" of buildings in Kuwait, especially those with western style designs.[67] Hence, in addition to the role of Demand Side Management (DSM) strategies in lowering energy consumption rates in the residential sector [68] – or the built environment in general – generating on-site renewable electricity or making use of solar energy for heating/cooling systems should also contribute to this end, thus enhancing the sustainability of buildings. Furthermore, the procurement and use of such technologies, when promoted and adopted through the right measures (legislative or financial), should lead to the flourishing of a new market.

Integrating renewable energy sources into a building's design is not unknown practice in Kuwait, as – back in 1984 – the Kuwait English School became the first building in the Middle East to harness 24.2 KW of solar energy through BIPV panels.[69] Unfortunately, aside from this early development, sustainable design did not take root in the country until 2008, when plans for Kuwait's first Gold LEED Sabah Al Ahmad International Financial Center were unveiled to the public. The design of this building uses PV panels and wind turbines to produce electricity – though the capacity of these renewable sources have not been revealed – and was registered with and pre-certified by the USGBC.[70] However whether such a development is underway is not clear, as there has been no communication in public about it. Besides, Kuwait has yet to formally create its green building council.[71]

On the other hand, recent developments in the field of BIPV have come up to stage. Kuwait Ministry of Electricity and Water plans to integrate 1MW worth

67. A. Al-Mumin and A. Al-Mohaisen, "Assessment of the Kuwaiti Residential Buildings with Respect to their Suitability to the Hot Desert Climate," *Challenges for the 21st Century, Proceedings of the 28th World Congress On Housing* (Abu Dhabi, United Arab Emirates, 2000), 461–468.

68. The study on occupants' behavior in the Kuwaiti residences recommends occupancy-sensed lighting and even occupancy sensing setback thermostat be used as part of these strategies. See Al-mumin, Khattab and Sridhar, "Occupants' Behavior and Activity Patterns."

69. N. W. Alnaser, "Towards Sustainable Buildings in Bahrain, Kuwait, and United Arab Emirates," *The Open Construction and Building Technology Journal* 2 (2008).

70. Press release, available at http://www.ameinfo.com/156812.html . USGBC stands for US Green Building Council; its purpose is to help transform the way buildings are designed, built and operated for a healthier society, more quality of life and sound environment.

71. Kuwait Green Building Council is registered as a "prospective green building council" on the World Building Council website www.worldgbc.org/site2/

of solar panels on the rooftops of two of their buildings, [72] and the civil aviation authority has plans to build a Gold LEED design airport terminal that will integrate solar panels to produce electricity, starting from 2012.[73] Yet, it is unclear as to when exactly these plans will come to fruition.

Investments

In addition to the venture capital fund set up by KPC in 2006, public and private Investment Funds in Kuwait have shown interest in the renewable energy industry.[74] However, the investment policy of Kuwait Investment Authority (KIA) indicates that the Kuwait government remains very unadventurous in this sector. KIA has considered opportunities in renewable energy while it was made clear that this had to be conditioned by the “viability of these technologies” and the long-term positive returns of such investments.[75]

Nevertheless, the National Technology Enterprises Company (NTEC), which is a fully owned subsidiary of KIA since 2002, has been active in private equity and venture capital investments on the international market, acting as a technology projects development company and investing internationally in three main sectors, i.e., life science; energy water and clean technology; and information and communication technologies. Studying its portfolio, one observes that energy supply and demand management, fuel cells systems, energy storage solutions, or carbon reduction issues remain the main focus of NTEC clean tech investments, and it has devoted some of its resources in these areas.[76]

On the other hand, across the investment banking industry in Kuwait, we observe the emergence of an increasing interest in renewable energies. Investment companies like KAMCO or the investment department of the Kuwait Finance House

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72. http://www.meed.com/sectors/power/renewable-energy/kuwait-receives-bids-for-solar-project/3108913.article

73. http://www.dgca.gov.kw/AxCMSwebLive/EnNewTerminalProject.cms

74. For information on KPC fund, see section on Renewable Energy in the Oil Sector.

75. “Kuwait Wealth Fund Mulls Renewables, Eyes Italy,” Trade Arabia, Kuwait, September 29, 2009. http://www.tradearabia.com/news/BANK_167966.html; The Kuwait Investment Authority (KIA) is an autonomous government body responsible for the management and administration of the General Reserve Fund (GRF), and the assets of the Future Generations Fund (FGF), as well as any other funds entrusted to it by the Minister of Finance for and on behalf of the State of Kuwait: http://www.kia.gov.kw/En/Pages/default.aspx

76. National Technology Enterprises Company website, http://www.ntec.com.kw/Client/content.aspx

(KFH) have considered opportunities in RES industries.[77] Being clean technologies that help protect the environment, RES have been presented to Muslim investors as offering investment opportunities beneficial to the well-being of humanity. Similarly, the Sharia-compliant KAMCO Energy Services Fund, which was launched in 2007, was the first hybrid energy fund in the GCC countries, offering equity investment opportunities in both the conventional (oil, coal and gas) and alternative (wind, solar, bio-fuels and fuel cells) energy industries.[78]

In comparison with other sectors, such as real estate or oil and gas, investment in RES remains small; nevertheless, the relative diversity of Kuwait's venture funds which deal with clean and renewable energy industries is a positive sign, as they will enhance confidence in the relevance of such technologies to future economic or energy developments.

Education, Vocational Training, and Technical Awareness

Apart from the leading role of KISR in promoting Renewable Energy research and utilization, other public and private institutions in Kuwait are supporting knowledge and skills training in this field. Kuwait hosts two major public higher education entities: Kuwait University and the Public Authority for Applied Education and Training (PAAET), and both are set to introduce programs to educate, train or upgrade Kuwaiti students and workforce in alternative or clean energy technologies.

For instance, the research administration of Kuwait University explored the possibility of initiating a national research project in Alternative Energy and Photovoltaic with the Belgium-based Interuniversity Microelectronics Center (IMEC). The university also collaborated with Boeing Company to evaluate the university research infrastructure, its research and development (R&D) activities, as well as its capabilities in the field of renewable energy, as one of the main

77. Speaking to the ArabianBusiness.com, Abdul Nasser Al-Subeih, the acting assistant general manager for investment sector of the KFH (Baitak), said the bank was studying projects with a view to invest in the industry http://www.menainfra.com/news/kuwati-bank-to-invest-in-green-energy/

78. KAMCO is KIPCO's Asset Management Company; Kamco Energy Services Fund: http://www.kamconline.com/kamcoTest/CustomPage.aspx?pageId=143&language=en

priorities for the research department. [79]

PAAET – through its two different entities, Applied Education and Training Services – has the objective of developing and upgrading manpower to meet the challenge of shortfall in technical manpower. The authority works towards diversifying Kuwait's national economy by training students for careers beyond the oil industry, including renewable energy sector.[80]

Scientific associations and societies also contribute to the effort; in 2008, Kuwait Foundation for the Advancement of Science (KFAS) organized workshops on "Alternative Energies for Water Desalination Applications" as part of its Water Resources Program activities. In 2009, the Kuwait Society of Engineers, which organized the World Federation of Engineering Organizations (WFEO) General Assembly meetings in Kuwait, dedicated the WFEO International Engineering Congress (EC) to explore the latest developments and innovations in alternative energy technologies and to disseminate technical information on solar and wind energy applications as well as clean technologies in the region.[81]

On the international cooperation front, the Renewables Energy Academy (RENAC) of Berlin, which previously provided Photovoltaic and Wind training program to representatives of KISR,[82] has signed an agreement with the National Technology Enterprises Company (NTEC) [83] to establish a training center in Kuwait specialized in Renewable Energies, which would enhance the knowledge of technicians, engineers, public and private decision-makers, investors and developers in the areas of renewable energy and energy efficiency. Through such cooperation, Kuwait aims to gain full expertise in all aspects relevant to RE market development and growth, such as calculations, financing, bankability, marketing, legal aspects, and contracts.

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79. IMEC is a research institute focusing on photovoltaic energy. See Kuwait University website, http://www.kuniv.edu/ku/News/KU_003985

80. More details on http://www.paaet.edu.kw

81. More details at http://www.ec2009kuwait.org/default.aspx

82. Photovoltaic and Wind training program for representatives of KISR included software training on wind farm design, visual impact and standard noise-propagation analysis; or covered visits of the whole PV value chain with deep insights in new technologies, research, quality control, and working practice. See RENAC website at: http://www.renac.de/index.php?id=33&L=1

83. NTEC, which is the investment arm of Kuwait technology development strategies, has also the objective to assist the relevant authorities in the development of nationals' technical skills and encourage their participation in high-tech projects. For more information on NTEC, see section on investment and NTEC website at: http://www.ntec.com.kw/Client/News.aspx

Contrary to common expectations, the training required to manage and operate RES technologies seems to precede the widespread use of such technologies in the Kuwaiti context. In other parts of the world, the training of personnel in the use of technologies follows the adoption of such technologies.

Renewable Energy Outlook

The discourse about renewable energy sources in Kuwait is diverse and originates from different institutions. Awareness about the benefits of RES seems to be widely shared among the different Kuwaiti communities. Support for alternative energy research and applications, scientific events, or training has been expressed by Kuwaiti institutions, research centers and companies alike. In the long term, if the nuclear energy option is not brought again to the table, renewable energy schemes seem to have an advantage.

Nevertheless, more than being aware of existing sustainability challenges, leaders and decision-makers need to transform awareness into policies; as evidenced by international experience, top down binding targets and regulations seem to be the way to guarantee action.[84] For, despite the positive stance in Kuwait, the country has not kick-started its renewable energy plans yet. It seems that potential RES deployments will follow a project-basis development pattern – sometimes as public infrastructure initiated by the government – or as public private partnerships, where Independent Power Production schemes will be complemented by power purchase agreements with Kuwaiti authorities.

At any rate, strategic imperatives for the deployment of RE technologies in Kuwait could be about water security and energy saving, especially in the built environment. Studies have shown that solar thermal facilities and BIPV are particularly suitable to the country's solar potential as well as to its seasonal and sectoral water and electricity demand.

For the time being, Kuwait may lack a cohesive renewable energy technology strategy; however, the country's different approaches to this sector can build up into forming an effective national plan for the development of such resources. According to Kuwait's own experts, successful deployment of RE technologies in their country will depend on:

- Predictable and affirmative energy demand control and non-discriminatory policies to attract investors;

84. EU Climate Commissioner Connie Hedeggard's statement during the World Climate Summit 2011 in Durban (Report by Barbara Lewis of Reuters carried in the *Gulf Today,* December 13, 2011).

- Integration of the RES option(s) into energy policies, scenarios and cross-border trading, as part of a portfolio of energy sustainability measures;
- Enabling RES laws and regulations on licensing, commissioning, safety and liabilities;
- International cooperation and technology transfer as well as acceleration of R&D, in particular on the viability of technology;
- Building of several cost-effective large-scale demonstration plants; and
- Allowing involvement of all stakeholders in decision-making on energy trading and technology implementation.[85]

85. Saad Al-Jandal, "Gulf Clean Energy Prospective and the Role of Renewable Resources."

Chapter Three

Oman

Electricity Expansion and Restructuring

Population growth and the expansion of heavy industry in cities such as Duqum, Sohar, and Salalah have put a strain on Oman's power infrastructure and, by extension, its gas reserves.

The country experienced severe power cuts in the summer of 2009 and 2010, reflecting its difficulties in bringing sufficient electricity production capacity to the grid. As per Oman Power & Water Procurement Company (OPWPC) – the single buyer of electricity and water in Oman – peak power demand reached 3,856 MW in 2010, a 46.4 percent increase since 2005. This was too high a demand to avoid occasional outages; indeed, during the same period, the generation capacity, which registered 4,054MW in 2010 for the main interconnected system (MIS) and the Salalah system together,[1] increased by 46.3 percent, slightly less than the peak demand growth rate.

In fact, electricity demand is projected to rise in the future due to increasing population as well as the government policy for economic diversification, which has

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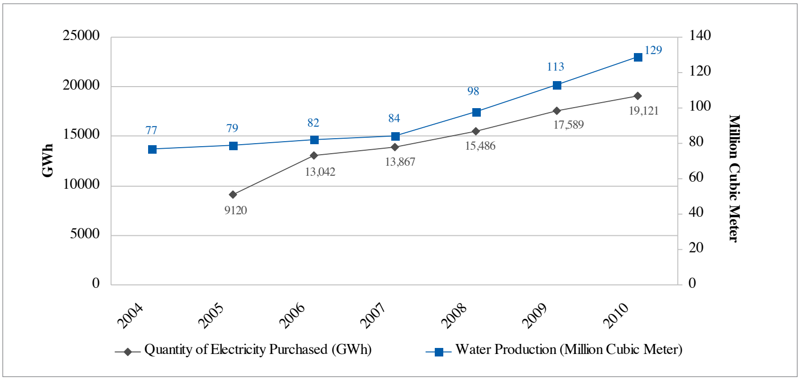
1. Two power networks exist in Oman: the main interconnected system (MIS) covers more than 90 percent of the country and the Salalah System the remaining 10 percent. Peak demand in the MIS is bound to reach 5,488MW in 2015, 5,923MW in 2016; and in the Salalah System it is forecasted to reach 638MW in 2015 and 678 MW in 2016. OPWPC's *Annual Report* for the year 2010 available at: http://www.omanpwp.com/PDF/OPWP%202011%20Annualreport%20English.pdf ; and Verity Ratcliffe, "Power Capacity Additions Move Forward in Oman," Special Report, *MEED* Issue 30 (July-August 2011), available at http://www.meed.com/sectors/power/power-generation/power-capacity-additions-move-forward-for-oman/3105332.article

led to the establishment of large industrial and touristic projects all over Oman's regions. Thus, it is forecast that peak demand will reach 5,900 MW in 2015 and 6,658 MW in 2016, leaving no choice to the public authorities but to turn to the private sector for help through Independent Power and Water Projects (IPWP). Indeed, the total capacity is likely to reach around 7,300MW by 2016 if no construction delays occur and if the government secures the necessary feedstock to power new stations.[2]

Growth in Electricity and Water Consumption - Oman



The total quantity of electricity consumed in Oman has more than doubled in five years. Figures represent the sum of electricity purchased from the main electricity grid and from the Salalah IWPP. Water production has also seen an acceleration of its growth in recent years.
Source: Based on statistics from Oman Power and Water Procurement Company's (OPWPC) *Annual Reports*, 2005-2010

In the meantime, temporary electricity generation units were set up by OPWPC as it was aware that delays in tendering new IPWPs meant that neither MIS nor the Salalah power system could meet seasonal peak demands during the summer.[3]

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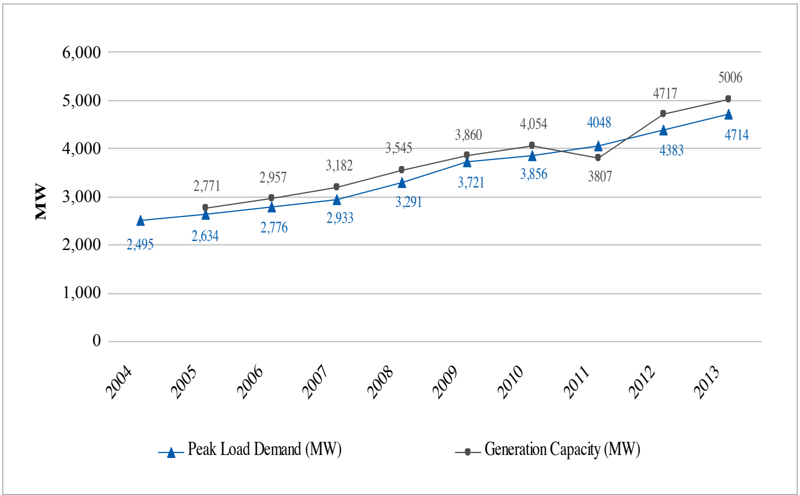
2. The Independent Power and Water projects to be constructed in Oman include a planned 1,000MW IWPP in Duqm, a gas-fired 445MW IWPP in Salalah, and two other IPPs of about 700MW each in Sohar 2 and Barka 3. These plants are expected to be completed by 2012 in Salalah, by 2013 in Sohar and Barka and by 2016 in Duqm. There are also plans to set up a gas-fired IPP in the industrial area of Sur with a first phase capacity of 400MW by the summer of 2013, that could be expanded to 2,000 MW later on. See Digby Lidstone, "Muscat Faces Fuels Dilemma," *GCC Electricity 2010*, *MEED* Supplement (2010); and Bernadette Redfern, "Oman Power Schemes Go Green," *Arabian Power and Water Report 2011*, *MEED* (2011).
3. Temporary generation capacity for MIS is 115MW and 60MW for the Salalah system. Both capacities are diesel-fired and are provided through Rural Areas Electricity Company. See

As in most countries of the region, annual power demand in Oman is highly seasonal; summer demand is more than double that in winter, with a peak occurring during July and August – especially in the residential sector – due to the intensive use of air cooling. More generally, the residential sector is responsible for 55 percent of the total electricity demand in the MIS, followed by the commercial, the governmental and the industrial sectors which accounted for 20, 15, and 8 percent, respectively in 2009.[4]

Oman - Electricity Capacity and Peak Load 2004 - 2013



Oman's electricity's supply system lacks flexibility, which occasionally creates severe power cuts. Peak demand figures represent the sum of peak demand from the main electricity grid, as well as the Salalah IWPP.

The energy requirements for the country's future development will be tackled via the private sector's Independent Power and Water Projects (IPWP).

Source: (2004-2010): Based on statistics from Oman's Power and Water Procurement Company (OPWPC) *Annual Reports* 2005- 2010. (2011-2013): Based on estimates from OPWPC's 7 Year Statements, 2011-2017

OPWPC's *Annual Report* for the year 2010, 17.

4. In particular, peak hours are between three and five in the afternoon, and again between 11 pm and 4 am in the summer. See A. Al-Badi, A. Malik, K. Al-Areimi and A. Al-Mamari, "Power Sector of Oman –Today and Tomorrow," *Renewable and Sustainable Energy Reviews* 13, Issue 8 (October 2009): 2192-2196; A.H. Al-Badi, A. Malik, and A. Gastli, "Sustainable Energy Usage in Oman – Opportunities and Barriers," *Renewable and Sustainable Energy Reviews* 15 (2011): 3780-3788;

Back in 1999, the Omani government started planning the restructuring and privatization of the electricity and water sectors, a reform put into practice only in 2004. The Authority for Electricity Regulation (AER) was established to regulate the electricity and related water sector in Oman, secure provision of electricity in all parts of Oman, develop effective economic operation of the sector, and protect the environment. Besides adapting to the evolving structural changes in the electricity market regulation, independent companies set up for this purpose and involved in the generation and procurement process[5] would now need to think about their generation mix.

Apart from the temporary generation capacity set up by the OPWPC, the primary fuel resource for both the MIS and Salalah generation systems – serving the majority of people in Oman – is natural gas. Almost 99 percent of the Sultanate's power generation is based on this resource which totaled 6.3 billion cubic meters in 2010, a 91 percent increase from the 2005 figure.[6] However, Oman's gas supplies have been largely committed to export and this in turn has resulted in domestic shortages for power generation, forcing the country to import gas. The remaining electricity production – about 310 GWh – is provided by the Rural Areas Electricity Company, whose diesel generators, with a total installed capacity of 447MW, secure provision of power to the scattered rural areas of the country that are not connected to the grid. It must be mentioned that this is done at a higher electricity price per KWh than that offered by the other power systems in Oman. [7]

It is clear that electricity generation in Oman can benefit from the introduction of renewable energy sources, and small and large solar, wind or hybrid electricity projects can be deployed; as we will see later, the country is blessed with these resources, which should help the authorities mitigate shortages of fossil fuels or offer a more economic and modern infrastructure as well as a cleaner environment in its countryside.

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5. For more details on the market structure and the different companies responsible for electricity generation and water desalination in Oman, see Al-Badi, Malik, Al-Areimi and Al-Mamari, "Power Sector of Oman."

6. The 2010 amount of natural gas used for electricity production represents 25.4 percent of Oman's total production for the same year; percentages are the author's calculation based on OPWPC statistics in OPWPC *Annual Reports* from 2005 to 2010 and the US Energy Information Administration statistics in *Oman Full Country Analysis Brief* (February 2011) available at: http://205.254.135.7/countries/cab.cfm?fips=MU

7. Al-Badi, Malik, Al-Areimi and Al-Mamari, "Power Sector of Oman"; and Al-Badi, Malik and Gastli, "Assessment of Renewable Energy Resources Potential in Oman."

Increasing Demand for Desalinated Water

In 2000, assessments of water availability and the development of its future demand pushed the authorities in Oman to adopt a National Water Resources Master Plan for 2001-2020. The plan stated that, in order to meet future demands, an additional supply of water amounting to 330 million m^3/year would be required. Although the Sultanate had already done a lot to conserve its water resources, in 2001 the government stressed that in addition to multiple regulations related to sustainable utilization, exploration, conservation, and recycling of available natural resources, increasing the use of desalinated water for domestic purposes was necessary. As almost 40 percent of the total area of Oman is affected by salinity, regulated desalination was also recommended for the use of wells.[8]

In general, desalinated water makes an important contribution to water supplies in Oman. The total production of desalinated water in the Sultanate reached 129 million m^3/year in 2010, which was estimated to be 80 percent of the potable water supply. This production increased between 2004 and 2010 at an annual growth rate of 11.2 percent, and will continue to do so even though OPWPC predicts a shortfall in Muscat and the coastal area in the coming four years.[9]

Gas Shortfalls and Economic Expansion

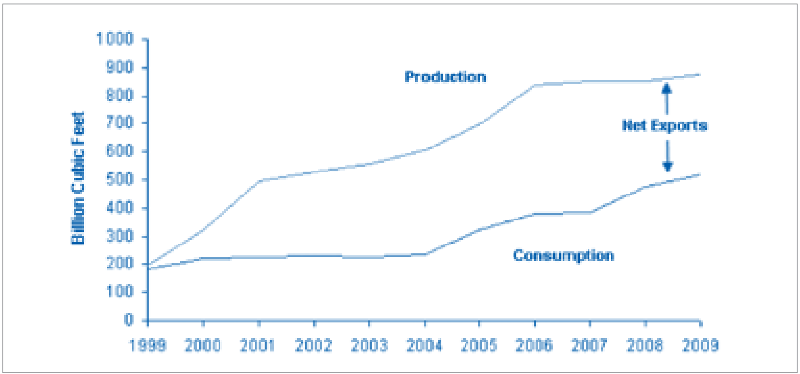
Domestic energy consumption in Oman is entirely based on oil and natural gas – 33 and 67 percent in 2004, respectively.[10] Together they accounted for 81 percent of the country's export revenues and 46 percent of its gross domestic product (GDP)

8. FAO Report, Chapter on Oman, 308-309.
9. As per the Food and Agriculture Organization (FAO), in 2003 desalinated water accounted for eight percent of total water supplies in Oman, which approximately amounted to 105.7million m^3/year. The remaining was supplied by groundwater (89 percent) and treated wastewater (three percent). See FAO Report, 303 -305. The desalinated water projection figure, however, does not agree with OPWPC statistics, which puts it at around 75 million m3/year (OPWPC *Annual Report 2010*). Water supply shortfalls in Muscat discussed in Redfern, "Oman Power Schemes Go Green."
10. Al-Badi, Malik and Gastli. "Assessment of Renewable Energy Resources Potential in Oman." Oman's consumption of petroleum products has more than doubled and its natural gas consumption rose by 135 percent between 2000 and 2009 reaching 115,000 barrels per day (bbl/d) and a total of 520 billion cubic feet (Bcf), respectively, in 2009. These increases are attributable to the country's expanding petrochemical sector and vehicle fleet along with Oman's industrialization and population growth; US EIA, *Oman Full Country Analysis Brief*.

in 2007 – up from 76 percent and 40.5 percent in 1997, respectively.[11] It is evident that Oman's economy has grown more heavily dependent on oil and gas revenues.

In fact, the Sultanate sought to increase its natural gas production to meet rising domestic electricity demand on the one hand, and, on the other, increase exports of liquefied natural gas (LNG) and provide stock for enhanced oil recovery projects in its mature oilfields.

Omani Natural Gas Production and Consumption 1999 - 2009



Re-injection of natural gas to increase oil production takes up a rising proportion of domestic production; while electricity generation is almost 99 percent based on the same resource. In 2007, natural gas imports from Qatar reached 8.3 percent of the country's own daily production (EIA and OPWPC).

Source: EIA

As per the US Energy Information Administration (EIA), in 2010, Oman produced 863,000 barrels per day (bbl/d) of total petroleum liquids and about 2.4 billion cubic feet per day (Bcf/d) of natural gas; however, although the country is a net exporter of oil and gas, shortfalls in natural gas production prompted Oman in 2007 to begin importing increasing supplies of this commodity – around 200 million cubic feet per day (Mcf/d) – for use as feedstock in electricity generation.12 Besides, the lack of natural gas resources has impeded progress in industrial diversification. As Oman's natural gas is currently largely committed to LNG export projects and the expansion of its natural gas-powered industries, including oil extraction,

11. Gulf Organization for Industrial Consulting, *The Gulf Statistical Profile 2008*; tables 2.3 and 3.2.
12. Oman's gas imports represent around 8.3 percent of the country's own daily production. They are channeled through the Dolphin Pipeline system, which transports 2 billion cubic feet per day (Bcf/d) of natural gas from Qatar to neighboring UAE and eventually to Oman by way of the Fujairah-Al Ain pipeline. US EIA, *Oman Full Country Analysis Brief.*

replacing some of the fossil fuel-based electricity through the use of renewable energy sources can help the country save on domestic consumption and free up more gas to power its industry or extend its reserves for export before it becomes a net importer. In addition, the deployment of renewable energy technologies would help Oman reduce its carbon footprint.

Industrialization and Protection of the Environment

In the past, oil has fueled the development of Oman; however, the authorities learned that the country's modest petroleum resources will not be enough to cater for such socio-economic needs in the future; hence, they pushed for economic growth through income-generating projects particularly in manufacturing, mining, agriculture and fisheries that were not completely harmless to the environment. With rapid industrialization, electrification, and considerable investments in oil exploration, Oman experienced its share of air pollution.[13]

For, although its carbon gas emissions per capita – at 13.69 tons/pop – is the lowest among the GCC countries, the country's total emissions continued to increase at an average annual growth rate of almost 10 percent between 2004 and 2009; this rate is among the highest in the region, only second to Qatar's for the same period (12.5 percent).

Oman, however, became a member of the Kyoto Protocol in January 2005, thus taking up binding targets for the reduction of greenhouse gas emissions. In this context, both the depletion of oil and the potential environmental impact of industrial activities can be drivers to deploy clean technologies and protect the environment. Moreover, following a study by the Authority for Electricity Regulation (AER) on the potential of Renewable Energy Sources (RES) in Oman, the country's Ministry of Environment and Climate Affairs announced in 2009 that it was in the process of setting up a Designated National Authority (DNA) to facilitate and administer "clean development mechanisms" (CDMs) in Oman.[14] Such an environmental approach would encourage the utilization of renewable energy by the different Omani entities.

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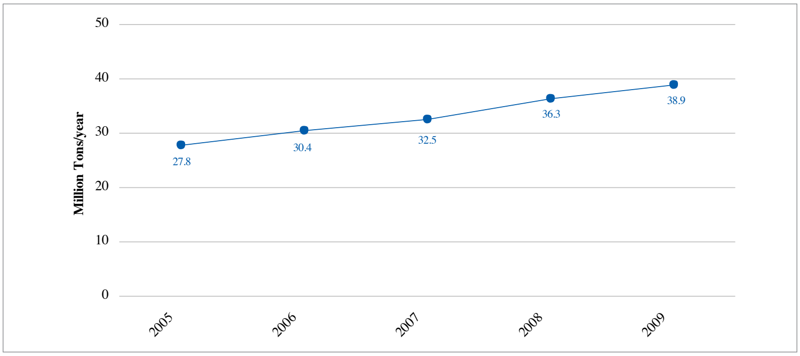
13. Joseph A. Kechichian, "Emerging Environmental Concerns: A Perspective from the Sultanate of Oman," in *Challenging Environmental Issues*, edited by J.G. Jabbra and N.W. Jabbra (Brill, 1997), 31-47.

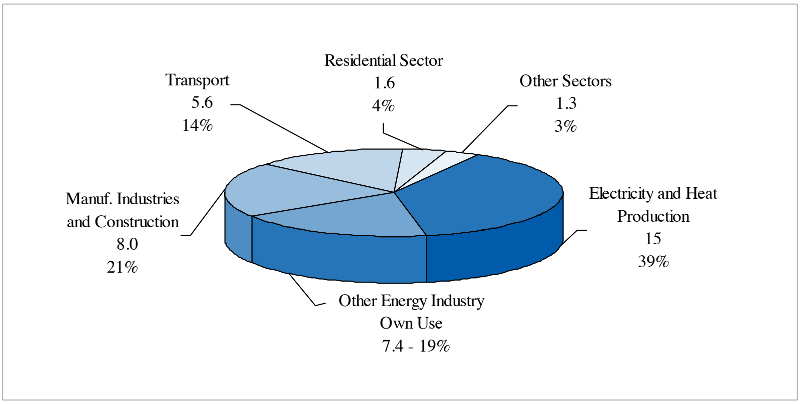
14. AER, *Study on Renewable Energy Resources,* 2008 available at http://www.aer-oman.org/index.php?option=com_content&view=article&id=146 ; also see *International Energy*, "Oman Eyes Renewable Energy," available at http://en.in-en.com/article/News/Renewable/html/200806237313.html

Oman CO_2 Emissions 2005 - 2009



Source: Based on IEA, *CO_2 Highlights* (2011)

Oman CO_2 Emissions from Fuel Combustion in 2009 by Sector (million tons)



In the past five years, Oman's CO_2 emissions have increased by the steady rate of 10 percent per annum. CO_2 emissions originate from diverse sectors of the economy but mostly from Electricity and Heat production (39 percent).

Source: Based on IEA, *CO_2 Highlights* (2011)

As experts predict that the Sultanate's oil reserves could dry up in 40 years' time, [15] alternative sources of energy will be needed to cater for at least one-third of Oman's total energy consumption that is today met by oil. In the light of the AER

15. For example,Thomas Blaschke, professor of Geoinformatics at the University of Salzburg and Deputy Director at Center for Geoinformatics in Austria. See *Muscat Daily* January 2012.

study's conclusions, policy schemes and funding mechanisms (such as CDMs) should be developed to support investment and sustain widespread implementation of RE projects across Oman. In accordance with subsequent developments related to solar and wind energy in Oman, certification of CDM projects by the DNA should enable Omani as well as foreign companies to sell carbon credits in the open market.

Potential of Renewable Energy Sources (RES)

Oman comprises three main physiographical regions: the coastal plain, the mountain ranges and the internal, mainly desert plains region that lies between the coast and the mountains; these different regions occupy around 3, 15, and 82 percent of the total area of the country, respectively. The country's climate, different from one region to another, is generally considered to be arid to semi arid, hot in the summer with some humidity in the coastal areas and moderate throughout the year in the higher lands and the south-western Dhofar region.[16]

In particular, solar radiation mapping in Oman has shown a high ratio of sky clearness (about 342 days/year) and a significant potential for solar energy all over the country during the whole year. The majority of the lands receive daily total (direct and diffuse) solar radiations ranging between 5,500-6,000 Wh/m^2/day in July and 2,500-3,000 Wh/m^2/day in January.[17]

Photovoltaic Energy

More specifically, in a study conducted by the German Aerospace Center (DLR), the Global Horizontal Irradiance (GHI) was found to be 2,050 kWh/m^2 /year on a surface tilted at Oman's latitude angles, that is between 16°40′ and 26°20°′ north. The economic PV potential was evaluated to be roughly 4.1 TWh/year.[18]

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16. Karen Frenken (ed.), *Irrigation in the Middle East Region in Figures*, AQUASTAT Survey – 2008, FAO Land and Water Division (2008), Oman Chapter: 299-310. Meteorological data collected by the Directorate General of Civil Aviation and Meteorology throughout Oman are available on http://redof09.ren-oman.net/presentations/Meteorology.pdf Available data include: Air temperature, Dew point temperature, Relative humidity, Atmospheric pressure, Surface wind speed/direction, Solar radiation, Sunshine duration, and Ground surface temperature.
17. Adel Gastli and Yassine Charabi, "Solar Electricity Prospects in Oman Using GIS-based Solar Radiation Maps," *Renewable and Sustainable Energy Reviews* (2009), doi: 10.1016/j.rser.2009.08.018
18. German Aerospace Center (DLR), *Concentrating Solar Power for the Mediterranean Region,*

Reviewing solar radiation for 25 locations in Oman, a study by the Engineering College of Sultan Qaboos University (SQU), showed that Marmul, Fahud, and Sohar have the highest average daily GHI in the country ranging from over 6 KWh/m^2/day (for Marmul) to almost 5.7 KWh/m^2/day (for Sohar). Coupled with data on sunshine duration in these locations, results found that Marmul was the best site, followed by Sohar and Fahud, for PV electricity production, with a capacity factor of about 0.206, corresponding to about 1,800 hours of PV full load operation. Masirah, Salalah and Sur were found to have the lowest GHI and capacity factors values, a fact that is mainly due to summer rain or frequent fog periods. The same study showed that from a PV power plant of 5MW installed in these 25 locations, the renewable electricity produced each year would vary from 9,000 MWh at Marmul to 6,200 MWh at Sur (the mean value would be 7,700 MWh for all locations). The capacity factor of the PV plants varies between 20.6 percent and 14 percent, respectively, and the cost of electricity (COE) varies between \$210/MWh and \$304/MWh. Although the COE from the PV plant under study was found to be higher than that of subsidized fossil-fuel based plants, the study shows that at Marmul, PV energy is competitive with diesel-based electricity generation (as used today in Oman's remote territories) even without considering the environmental benefits. These would eventually correspond to reducing 6,000 and 5,000 tons of greenhouse gas (GHG) emissions resulting from commonly used diesel and natural gas generators, respectively.[19]

So far, however, PV applications in Oman are limited to some installations of solar power systems for lighting, water heating, water pumping, seismic monitoring stations, and TV transponders. Oman Solar Systems Co. LLC (OSS) and Petroleum Development Oman (PDO) also place to install photovoltaic power systems for 12 radio-base stations at PDO's operation sites in the interior or for cathodic protection of its pipelines.[20]

Institute of Technical Thermodynamics, Section Systems and Technology Assessment (2005), 56-57.

19. The study found that the global solar radiation varies from 4 kWh/m^2/day at Sur to about 6kWh/m^2/day at Marmul, while the average value in the 25 locations is more than 5 kWh/m^2/day. The Capacity Factor is defined here as "the ratio of the average power produced by a power station over a year to its rated power." See A.H. Al-Badi, M.H. Albadi, A.M. Al-Lawati and A.S. Malik, "Economic Perspective of PV Electricity in Oman," *Energy* 36, (2011): 226-232.

20. The activities of Oman Solar Systems Co. LLC (OSS) include design, manufacture, installation, testing and commissioning of small solar and wind power systems for lighting, heating, or pumping. See W.E. Al Naser and N.W. Al Naser, "Solar and Wind Energy Potential in GCC Countries and some Related Projects," *Journal of Renewable and Sustainable Energy* 1, 022301 (2009); also in http://www.omansolar.com/project.htm

Recent developments and the interest shown by the governmental authorities and international investors, however, may allow a wider application of PV power in Oman.

Concentrating Solar Power (CSP)

Assessed in different studies, the Direct Normal Irradiance values in Oman were also found to be suitable for use of Concentrating Solar Power (CSP) technologies in the country. According to the German Aerospace Center (DLR) researchers, DNI amounts to 2,200 kWh/m^2/year, a performance indicator that, in conjunction with the selection of 'economically viable' sites, would yield 19,404 TWh of electricity per year. [21]

Similarly, based on the calculated yearly solar radiation per unit surface, the total exploitable area, and the efficiency of the technology used to convert solar radiation into electricity, some studies allowed the calculation of the yearly potential of electricity generation for different CSP technologies such as the parabolic trough, parabolic dish, Power Tower, and concentrating PV. These calculations showed that, if only 10 percent of the land of Oman with a slope less than 1 percent is designated as exploitable land for the parabolic trough CSP technology, then the total calculated potential of electricity generation – without any storage – would be about 7.6 million GWh/year, or 680 times the electricity supply in Oman in 2007 which was 11,189GWh..[22]

More specifically, a targeted examination of solar radiation was conducted over Wilayat Duqum, a newly developed city on the Strait of Hormuz and the Arabian Sea to serve as an Omani port for Gulf's crude oil export. Calculation of both DNI and GHI has confirmed the high solar potential and ratio of sky clearness during the whole year in the region. Mean GHI was found to vary from 4,059 Wh/m^2/day in December to 8,217 Wh/m^2/day in June, and DNI from around 3,100 Wh/m^2/day in December to around 6,500 Wh/m^2/day in June.[23] More particularly, studies by different colleges of Sultan Qaboos University have shown a very high potential for CSP technology in Duqum. For instance, based on Geographical Information System solar radiation calculation, geographical topology, and the master plan of

21. Economically viable sites are defined as CSP sites with DNI>2000 kWh/m^2/year. See German Aerospace Center (DLR), *Concentrating Solar Power*, 56-57.

22. For each CSP technology, the potential to generate electricity was found to be many multiples of the demand for electricity in Oman in 2007; in Gastli and Charabi, "Solar Electricity Prospects in Oman."

23. A.Gastli and Y. Charabi, "GIS Assessment of Large CSP Plant in Duqum, Oman" *Renewable and Sustainable Energy Reviews* 14, Issue 2 (February 2010): 835-841.

the Duqum region, the deployment of a 100 MW parabolic trough power plant, which should consume about 2.4 km^2 of flat land inside an industrial area of around 50 Km^2 , was shown to be technically feasible and economically viable. With a total solar radiation of 2,357 KWh/m2/year and a capacity factor of 40 percent, the calculated potential of electricity generated by such a plant would reach 1,018 GWh per year.[24]

Similarly, the potential for implementing combined electric power and seawater desalination plant in Duqum using CSP technologies was investigated. For this, two different options were considered; the first option combined a CSP plant with a thermal desalination unit (MED), and the second was to exploit only the electricity output of the CSP plant with a reverse osmosis (RO) desalination unit. According to the findings, it was concluded that both CSP/Reverse-Osmosis and CSP/Multi-Effect-Desalination systems have the medium-term potential to achieve base-load operation with less than five percent of fuel consumption of conventional plants, at a cost of water well below $0.4/$m^3$.[25]

Nevertheless, water requirements for CSP parabolic trough technology were estimated to amount to 4,800m^3/day in order to efficiently run a 100 MW plant. This, it was felt, would pose a serious problem given the scarcity of water in Oman.[26]

Solar Thermal Enhanced Oil Recovery

Interestingly, Petroleum Development Oman (PDO), the main oil company in Oman, is currently in the process of integrating solar steam generation from Concentrating Solar Troughs into an oilfield for thermal enhanced oil recovery (EOR). In July 2011, PDO awarded the first solar thermal Enhanced Oil Recovery (EOR) project in the region to US-based GlassPoint Solar. As part of the project, an array of 7MW would be constructed during 2012 to produce 11 tons/hour of high-pressure steam capable of extracting 33,000 barrels of oil.[27] This solar steam system

24. Results were compiled for five different CSP technologies: Parabolic Trough without storage (PTNS), Parabolic Trough with Storage (PTWS), Power Tower, Parabolic Dish, and Concentrated PV (CPV). Ibid., 840.

25. A. Gastli, Y. Charabi and S. Zekri, "GIS-Based Assessment of Combined CSP Electric Power & Seawater Desalination Plant for Duqum-Oman," *Renewable & Sustainable Energy Reviews* 14, no. 2 (February 2010): 821-827.

26. A.H. Al-Badi, A. Malik and A. Gastli, "Sustainable Energy Usage in Oman - Opportunities and Barriers," *Renewable and Sustainable Energy Reviews* 15 (2011): 3780-3788.

27. Florian Neuhof, "Oman Awards Gulf's First Solar-Enhanced Oil Recovery Contract," *MEED*,

should be fully integrated with an existing gas-fired boiler steam generation unit to provide 24-hour heating.[28]

Indeed, to make their aging oilfields more productive, virtually all of PDO's oil production currently utilizes primary and secondary recovery mechanisms. These involve pumping the oil as primary recovery technique, or – when the latter method is no longer effective – injecting water or gas into the reservoir to maintain its pressure and displace the oil from one well to more producing wells. It is, however, expected that within the next decade, over a third of PDO's production will come from more advanced tertiary recovery methods, such as EOR techniques.[29] Increasing amounts of electric power will thus be consumed, the bulk of which will be needed by recovery mechanisms, including new thermal EOR projects that use injected steam instead of gas to maintain reservoir pressure.[30]

The solar EOR project comes at a time when PDO is faced with the need to reduce the energy input requirements (gas burning) of thermal EOR projects, and of its power system in general. More generally, oil production-efficiency policies together with what can be termed an environmental approach to energy consumption had already prompted PDO to look for further gains through electricity and steam cogeneration, where waste heat from cogeneration stations could be used to generate steam for oilfield injection.[31]

August 4, 2011. It is reported that Oman currently uses 200 trillion British Thermal Units (Btu) – equivalent to 196 billion cubic feet – of natural gas a year for EOR activities.

28. PDO already uses solar photovoltaic systems in its well surveillance and seismic programs, http://www.oeronline.com/php/2009_june/cover2.php and http://www.pdo.co.om/pdoweb/LinkClick.aspx?fileticket=nw2fgxuJ%2BKw%3D&tabid=299&mid=633

29. PDO website, http://www.pdo.co.om/pdoweb/tabid/275/Default.aspx, ; and "The Middle East Learning Hub Brings EOR Training to the Region," *Al Fahal* PDO Newsletter, issue 369, April 2009, available at http://www.pdo.co.om/pdoweb/LinkClick.aspx?fileticket=nw2fgxuJ%2BKw%3D&tabid=299&mid=633; and *MEED*, http://www.meed.com/sectors/oil-and-gas/oil-upstream/enhanced-recovery-to-account-for-more-than-third-of-oman-production/3116393.article

30. *Oman Economic Review*, "Petroleum Development Oman: A Planet-Friendly Mindset Takes Over," June 2009, available at http://www.oeronline.com/php/2009_june/cover2.php

31. Cogeneration uses a "Heat Recovery Steam Generation" unit that is built adjacent to the power station to generate steam by utilizing the power station waste heat without additional fuel firing, hence providing a tremendous saving in the total production cost per barrel of oil recovered and reducing CO2 emissions. It also conserves the gas for future, higher value uses. See CH2MHill Energy Management and Planning, "Energy Management-Project Qarn Alam in Oman" available on: www.ch2m.com

In fact, as PDO has its own electricity system – a 1.2 GW capacity dedicated to its operations across over 120 oilfields throughout the Sultanate – [32] the use of cogeneration technology in the oil sector can equally offer huge potential for industrial-scale solar thermal energy applications. In particular, as steam injection (steam flooding) is a widely used EOR technique, high temperature steam generated from CSP technologies could be channeled into the existing steam distribution network of old oilfields to enhance their productivity. Such solar thermal EOR technique also reduces the amounts of natural gas burned to produce steam or simply injected into oilfields using gas-based recovery techniques.

Wind Energy

Active movement of the wind along the main coastline of Oman together with its summer and winter monsoon winds ensure sustainable renewable energy from these sources.[33] The country has an average wind speed slightly over five m/s and 2,463 hours of full load per year, which is considered to correspond to an economically viable potential of wind energy. [34]

Wind characteristics were also investigated for different locations in Oman. Average wind potential was assessed for a period of 10 years (1985-1994) for 12 locations, and it has been found that the three most promising sites for the economic harnessing of wind power are Thumrait, Masirah, and Sur.[35] In more recent studies (2002 and 2010), it was confirmed that these locations have good wind energy potential and that a fourth one, Qayroon Hyriti is the most suitable site for wind power generation. In seasonal approach estimation, it was also found that, in general, wind speed is higher during the summer months of June, July and

32. State-owned PDO has been producing oil and gas in the Sultanate of Oman for over 40 years. Capacity estimate of PDO power system is from Al-Badi, Malik and Gastli, "Sustainable Energy Usages in Oman."

33. S. Al-Yahyai, Y. Charabi, A. Gastli and S. Al-Alawi, "Assessment of Wind Energy Potential Locations in Oman using Data from Existing Weather Stations," *Renewable and Sustainable Energy Reviews* 14, Issue 5 (June 2010).

34. German Aerospace Center (DLR), *Concentrating Solar Power*, 56-57; Alnaser and Alnaser "Solar and Wind Energy Potential in GCC Countries."

35. The highest monthly mean wind speed ($\sim$10 m/s) long-term (i.e. over 10 years) was registered for Thumrait and ensues during the month of July; in Hilal A. Al-Ismaily and S. Douglas Probert, "Prospects for Harnessing Wind-power Economically in the Sultanate of Oman," *Applied Energy* 55, Issue 2 (October 1996).

August and is lower during the winter months of October and November. Similarly, calculations showed that the monthly mean wind speed and power density in Oman are higher during the summer, which positively matches the higher power demand during this season due to greater air cooling load.[36]

Evaluation of wind energy resources based on wind speed, wind power density, and concordance with electricity peak demand allowed the ranking of seven stations, namely, Qayroon-Hyrity, Thumrait, Masirah, Ras-Alhad, Jabal-Shams, Yalooni, Sur Joba, and Duqum, as having the highest to the least high wind power potential, respectively, in Oman. It is recommended though that high resolution Numerical Weather Prediction should be considered in the wind assessment process and be made available in Oman's weather station measurements.[37]

In this context, a case study was carried out for Masirah Island in 2009, and it has been concluded – like in the case study of 5MW PV plant at Marmul described earlier – that the cost of electricity generation by the hybrid wind-diesel system is considerably lower than the cost of diesel generation alone, the method that is currently in use in the country's remote areas. Having an installed capacity of about 9 MW (of diesel generators), 10 wind turbines of 900-kW rated power each were considered to demonstrate the economic viability of the proposed hybrid wind and diesel power generation.[38]

Another case study, focused on Najd's agriculture research station, 80 km north of Thumrait, investigated the economics of wind power generation. It showed that with the use of a 50-kW wind turbine, wind energy deployment is an attractive economic option for this region. Whereas the cost of electricity generated by diesel

36. The annual mean values of the wind speed of the observed and theoretical distributions were 5.06 m/s and 5.03 m/s for Masirah and 5.52 m/s and 5.40 m/s for Sur, respectively. The monthly mean wind power density records 501 W/m^2 in Masirah in July and reaches 520.85 W/m^2 for Sur in the month of August. See M. Yusof Sulaiman, Ahmed Mohammed Akaak, Mahdi Abd. Wahab, Azmi Zakaria, Z. Abidin Sulaiman and Jamil Suradi, "Wind Characteristics of Oman," *Energy* 27, Issue 1 (January 2002). Wind speed can reach 8.7 m/s at 100 m height in Qayroon Hyriti and about 8.40 m/s in Thumrait at the same height; for detailed wind characteristics in these and 27 other locations, see Al-Yahyai, Charabi, Gastli and Al-Alawi, "Assessment of Wind Energy Potential Locations in Oman."

37. Al-Yahyai, Charabi, Gastli and Al-Alawi, "Assessment of Wind Energy Potential Locations in Oman."

38. K. Qian, P.S. Solanki, V.S. Mallela, M. Allan and Ch. Zhou, "A Hybrid Power System using Wind and Diesel Generator: a Case Study at Masirah Island in Oman" (20th International Conference and Exhibition on Electricity Distribution [CIRED June 2009], Institution of Engineering and Technology Conference Publications, Volume 2009, Issue CP 550).

was estimated at about USD cent 0.143/KWh, the same was found to be only USD cent 0.084/ KWh when generated by wind – even in the most pessimistic case, i.e., when the annual energy produced by the selected turbine is only 104,300 KWh instead of 120,100 KWh. The study concluded that the turbine can be economically embedded into the diesel system as a fuel saver. [39]

On the other hand, a techno-economic evaluation of a 9MW wind power project in Duqum region, with an annual average of 5.33 m/s and a capacity factor of 0.36, showed that the cost of wind electricity for the base-case assumptions[40] is higher (costs range between $0.05 and $0.08 per KWh) than that of the existing gas-based electricity system (about $0.024/KWh). According to the study, this is due to the subsidized prices of domestically available natural gas. When international market prices of this fuel are used, the COE in Oman becomes four times higher, hence wind power becomes cheaper.[41]

Furthermore, a study conducted by AER in 2008 to investigate the feasibility of solar and wind energy in Oman, considered as commercial certain projects that would integrate these technologies. For instance, it has been confirmed that significant wind energy potential is available, and that - assuming the opportunity cost of $3/MMBtu and adding depletion premium of 3 percent annually - the COE produced by wind turbines and a gas plant are found to be broadly similar.[42] The AER study identified the long-term potential of two wind farms of 375 MW each in

39. The study provides detailed information on the selected wind turbine and the economic analysis assumptions (the total system cost is calculated at $80,000, the simple payback period of the turbine ranges between 5.1 and 5.9 years, and discounted payback is between 6.7 and 8.0 years at the 7.55 percent discount rate recently used by the Omani Government). See A. Malik and A.H. Al-Badi, "Economics of Wind Turbine as an Energy Fuel Saver – A Case Study for Remote Application in Oman," *Energy* 34, Issue 10, October 2009.

40. The main features of the base case are as follows: a wind system of five Vestas turbines with 1.8 MW of rated power and a Cut-in and Nominal speeds of 3.5 m/s and 12 m/s, respectively; a lifetime of 25 years and implemented with a feed-in-tariff (FIT) scheme of $0.10 per KWh for the 25 years; M.H. Albadi, E.F. El-Saadany and H.A. Albadi, "Wind to Power a New City in Oman," *Energy* 34, Issue 10 (October 2009): 1579-1586.

41. Assuming a fuel price of $10 per MMBtu (instead of local price of $1.5), the authors estimated the COE to reach $0.111 per KWh in Oman. See M.H. Albadi, E.F. El-Saadany and H.A. Albadi, "Wind to Power a New City in Oman," 1584; The study also investigates the 9MW wind project's economic viability in terms of its Net Present Value (NPV) – which roughly depends on the initial costs and the future income of the project in present time money – and the impact of different FIT schemes, discount rates, and capital cost allowance on facilitating or impeding such investments.

42. Authority for Electricity Regulation (AER), *Study on Renewable Energy Resources,* available at http://www.aer-oman.org/images/renewables%20study%20may%202008.pdf

Thumrait and Qairoon-Hyriti. It estimated that these farms would produce up to 2.3 TWh/year of electricity,[43] which roughly corresponds to 12 percent of Oman's 2010 electricity production, or 29 percent of the total wind electricity supply potential in Oman; the latter was estimated to be eight TWh/year by the 2005 DLR study.[44]

Surprisingly, today's wind applications in Oman are almost limited to wind-powered water pumping systems at remote sites like Heelat Ar Rakah, 70 km north of Thumrait. This experimental farm, established by the Ministry of Water Resources in 1996, is a research project dedicated to assess the use of brackish groundwater for crop irrigation. Electricity requirements of the site are met by two 50KW diesel generators and water requirement by PV solar desalination plant of $5m^3$/day. The wind system installed in the experimental farm consists of a 10KW wind turbine and was installed by OSS (Oman Solar Systems).

It is important to note that one year of monitoring has confirmed that wind energy can be used successfully for the extraction of groundwater and other loads in remote areas and that hybrid wind/solar/diesel electricity generating systems are collectively and entirely reliable to power all vital requirements in such locations.[45]

In light of all this, and particularly for locations ranked as having the best wind potential in Oman, investments in related technologies/applications are justified. More generally, starting from the fact that the price of fossil fuels energy in Oman does not reflect the real cost on the global market or the environmental impact of its use, solar and wind energy sources should be considered the most economically viable clean energies for the Sultanate, even though their costs are relatively high. Technological advances in their efficiency would lead to their faster and wider integration in the future energy mix of Oman.

Solar and Wind Pilot Projects

Acknowledging the fact that "gas shortages may adversely affect the electricity market in Oman," experts have recommended that "the electricity companies investigate the renewable potential and work with Omani government and

43. The interconnection of the Main Interconnected System and the Salalah Power System is precondition to harness such wind potential; in Authority for Electricity Regulation (AER), *Study on Renewable Energy Resources;* also in *Oman Eyes Renewable Energy*, available at http://en.in-en.com/article/News/Renewable/html/200806237313.html

44. German Aerospace Center (DLR), *Concentrating Solar Power*, 56.

45. Zaher Al Suleimani and N. R. Rao, "Wind-Powered Electric Water-Pumping System Installed in a Remote Location,", *Applied Energy* Volume 65 (2000): 339-347.

Authority for Electricity Regulation (AER) to establish policy support for renewable energy plants."[46] In fact, the AER, the Ministry of Environment and Climate Affairs, and the Public Authority for Water and Electricity (PAEW) have been active in promoting the development and use of renewable energy sources through the commissioning of RES feasibility studies or dedicated forums and seminars.

Renewable Power for Remote Locations

In 2008, COWI/SCO[47] was commissioned by the AER to identify sources of renewable energy in Oman and undertake initial technical and economic assessments of their potential use in electricity production. The study utilized information and data provided by various ministries, electricity companies, wastewater companies, Sultan Qaboos University, the Research Council, the meteorological department, Petroleum Development Oman (PDO) and the Royal Oman Police.[48]

While it acknowledged the availability – though limited – of biogas, geothermal and wave energy, the study stressed that Oman focus its attention on utilizing its large solar and wind energy resources. As a result, a road map for the development of renewable energy sources in Oman was outlined.

In particular, in areas that are exclusively served by increasingly expensive diesel-based power generation, there were clear incentives for the Sultanate to exploit advances in RE technologies in the face of growing electricity demand. So, in conjunction with the Rural Areas Electricity Company SAOC (RAEC SAOC),49 which is undertaking electricity generation, transmission and supply, and desalination activities in remote parts of the country, the study identified locations for the implementation of specific RE pilot projects.

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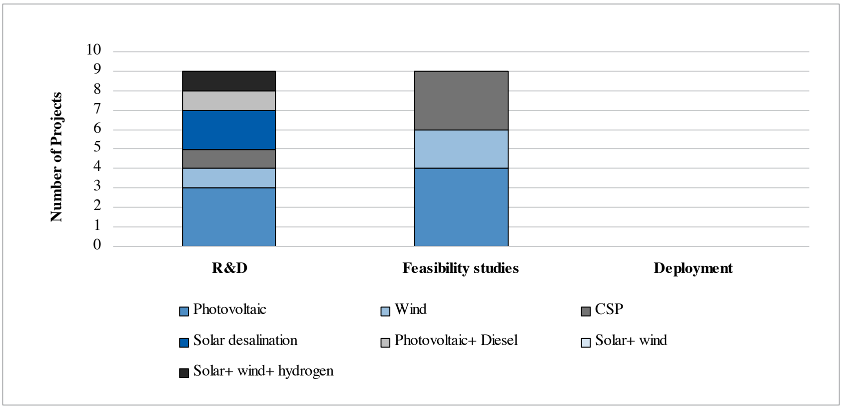
46. Al-Badi, Malik, Al-Areimi and Al-Mamari, "Power Sector of Oman."

47. COWI Denmark is a northern European Consulting group that provides services within the field of engineering, environmental science and economics; Silver Circle Overseas LLC (SCO) is a provider of solar products and systems for photovoltaic systems as well as for concentrating solar power installations.

48. Authority for Electricity Regulation (AER), *Study on Renewable Energy Resources.*

49. http://curtisoman.blogspot.com/2009/04/doing-business-in-oman-alternative.html. RAEC, which is operating under a license issued by AER, is a closed Omani joint stock company registered under the commercial companies' law of the Sultanate of Oman. The company is fully owned by the Ministry of Finance (directly 1 percent, and 99 percent through Electricity Holding Company SAOC. EHC is 100 percent owned by MOF).

Number of Renewable Energy Projects in Oman per Nature and Technology (up to 2012)



Despite several R&D and feasibility studies, no RES project has been deployed in Oman yet.
Source: Author's calculation

Within this framework, the AER invited developers to submit small project proposals – based on solar and wind energy sources, possibly hybrid systems – for rural locations identified by RAEC. This allowed the selection, during 2010, of six renewable energy pilot projects – including projects that incorporate thin film, silicon-based technologies or wind – that, when implemented, would allow RAEC to replace 10,683MWh of annual diesel generation with renewable sourced electricity and reduce diesel fuel consumption by 3.1 million liters per annum, thereby avoiding 8,298 metric tons of CO_2 per annum. In total, the six selected projects offer 6.6MW of renewable capacity at an investment cost of around RO8.1 million.[50]

Nevertheless, at the time of writing, these pilots have not yet been

50. RAEC and the selected projects' developers began implementation of two projects, and it was hoped that electricity production would start during 2011. The four other projects need further consideration but should be operational by the end of 2012 (see appendix: Table on RES Projects in Oman, esp. RAEC's Shortlisted Projects).The two pilots that are being implemented are: a 500 KW wind (2X250 KW turbines) project in Masirah Island, and a 100KW Photovoltaic energy project in Hij using thin film and mono-crystalline panels. The four other projects are: a 4,200 KW wind (2X2.1 MW turbines) project in Saih Al Khairat (wilayat Thumrait); a 292 KW Photovoltaic energy project in Al Mazyunah; a 1,500 KW Photovoltaic energy project in Hij; and a 28 KW Photovoltaic energy project in Al Mathfa. For more information on the projects proposals and the evaluation methodology, refer to: Authority for Electricity Regulation (AER), *Regulatory Statement Renewable Energy Pilot Projects – Status Report* (April 2010) available at: http://www.aer-oman.org/index.php?option=com_content&view=article&id=146

implemented. The lack of a legal framework and slow validation procedures are the main reasons for such delays.[51]

Large-scale Renewable Energy Deployment and Market Aspects

The AER/COWI study underlined the strong potential for developing the country's limitless access to solar energy through the establishment of large-scale grid-connected solar thermal CSP plants (50-200 MW). However, the study's recommendations called for further research to confirm its economic viability in Oman. In view of that, the Public Authority for Electricity and Water (PAEW) initiated in 2009 the appointment of international advisors to conduct a feasibility study, whose objectives were to evaluate different CSP technologies, identify possible locations, capacity, and needed legislative support, and develop appropriate risk allocation structures.[52] The study was completed at the end of 2010, where both PV and CSP Trough and Tower technologies were shortlisted, and where Adam and Manah in Al Dakhiliya region were identified as best locations for Oman's first large scale solar deployment.[53] It is worth mentioning here that the feasibility study also identified, but did not retain, Sohar and Ibri as appropriate locations for this deployment. In earlier academic studies, Sohar was identified as having the second best potential after Marmul for annual photovoltaic electricity supply; however, Adam was only ranked 12 for the same technology in this exercise.[54] All the same, at the end of 2011, the solar project was finally tendered by PAEW as a Build-Own-Operate (BOO) contract for the construction of a PV/CSP plant that would have a capacity of 200 MW, a cost of around $600 million dollars approximately, and be completed

51. Adil A-Gastli to *Times of Oman*, in "Call to Tap Solar Energy to Meet Power Demands in Oman," January 11, 2012, available at: http://www.timesofoman.com/searchdetail.asp?cat=&detail=53475&rand=8BsqGg8TdtloFFUaWqfShLl43A

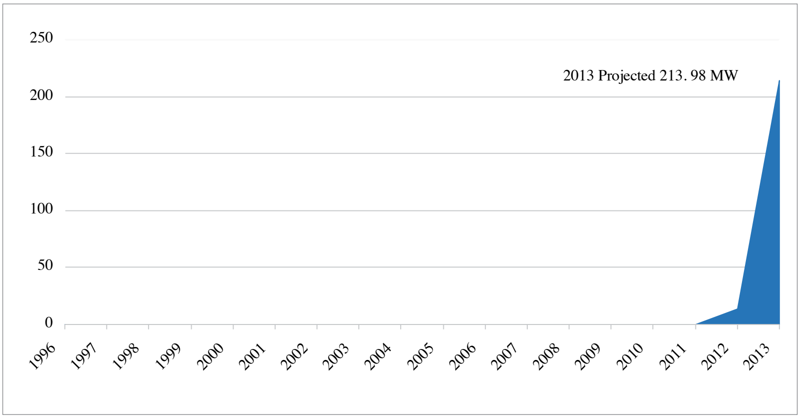
52. http://www.aer-oman.org/images/5re.pdf

53. "Solar Power Project Tender in Six Months," *Oman Times*, February 14, 2011 available at http://www.omaninfo.com/news/solar-power-project-tender-six-months.asp; and Hannah Uckat, "Market Overview and Update: Renewable Energy and Energy Efficiency in Oman," AHK Oman, available at: http://vae.ahk.de/en/business-news/oman/oman/artikel/marktueberblick-und-aktueller-stand-erneuerbare-energien-und-energieeffizienz-in-oman/?cHash=a85138cbb7068ef828b3dc50a83e04ca; Solar data have been collected since 2010 in those locations. According to Zawya.com, Worley Parsons Oman Engineering is the technical consultant of the CSP project.

54. The ranking was based on daily GHI, sunshine duration, and a virtual 5MW PV deployment in 25 locations in Oman. See Al-Badi, Albadi, Al-Lawati and Malik, "Economic Perspective of PV Electricity in Oman," Figure 3, p. 229.

by the end of 2013.[55]

RES Projects Oman - Cumulative Capacity (MW)



Should the Al Dakhiliya's solar power plant (CSP) be fully deployed, this would significantly boost Oman's overall RES capacity by adding 200 MW.
Source: Author's calculation

Whereas the 2008 AER study emphasized the positive role of some regulatory instruments such as feed-in-tariff in supporting RE deployment in Oman, PAEW is offering the developer of this medium- to large-scale solar project a long-term power purchase agreement (PPA) as financial incentive.

Incidentally, many studies have emphasized that clear and long-term RE policies should be established by the concerned authorities of the Sultanate in order to promote RE investments. Long-term power purchase agreements like the feed-in-tariff (FIT) schemes – where RE providers receive a fixed rate per unit of electricity injected into the grid for a guaranteed contract period – could prove to be the most effective policy. While reducing regulatory and market risks, FIT policies also should generate adequate competition among RE technologists.[56] However,

55. http://www.middleeasttenders.com/webpartner/infraoman/omanprojectsinfo.asp and "Oman PAEW - Adam/Manah Solar Power Plant," Zawya Project Monitor; available at http://www.zawya.com/marketing.cfm?zp&p=/projects/print.cfm?pid=060409012000; the 200 MW solar project is expected to be awarded by the second quarter of 2012. As per available information, such a large RE deployment has not been filed as a CDM project

56. Albadi, El-Saadany, and Albadi, "Wind to Power a New City in Oman." The authors recommend that Public Authority for Electricity and Water in Oman adopt feed-in-tariff (FIT) and Capital Cost Allowance (taxes reduction) policies for wind power development in the country; see p. 1585.

from the outset, PAEW seems to be of the view that a FIT policy is not necessary at this starting phase of RE development in the country. The company thinks that projects such as the 200 MW solar plant would be better managed through special purchase agreements, similar to the ones put in place for the Independent Power Production projects.[57]

Whether such contracts are sufficient for solar and wind energy sources to play an important role in the future energy mix of Oman remains to be seen. Nevertheless, the implementation of both the pilot and the large-scale projects will surely permit the testing of the performance and efficiency of different RE technologies in local conditions. Furthermore, as five out of the six pilot deployments as well as the 200 MW project are expected to be developed under the BOO scheme, AER and PAEW expect these public private partnerships to allow the development of local industry and the operating and maintenance capabilities related to these technologies within RAEC, Oman Power and Water Procurement Company (OPWPC), or other Omani entities and companies.[58] Building local capacity is considered one of the challenges Oman faces for the development of its RE sector.[59]

Education, R&D, and Industry

Aiming to provide the necessary scientific expertise and technical workforce for the development of a knowledge economy in Oman, the Research Council has recently approved a budget to fund studies for the development of RE technologies, studying their costs, economic feasibility, and means of dissemination, as well as developing related competencies and skills. The ministries of environment and climate affairs, transport and communications, and the AER, along with research institutions from the United States will collaborate with the SQU for the development of RE technologies in the Sultanate. It has also been emphasized that such collaboration should focus on the wider energy planning and management, investment, and research consulting fields.[60]

57. http://www.aer-oman.org/images/5re.pdf

58. Authority for Electricity Regulation (AER), *Regulatory Statement Renewable Energy Pilot Projects – Status Report*; and "Oman PAEW - Adam/Manah Solar Power Plant."

59. Mohammed Al Mahrouqi, chairman, Public Authority for Electricity and Water (PAEW), to *Times of Oman*. See Mrudu Naik, "Right Framework Required to Boost Renewable Energy Sector," *Times of Oman*, February 8, 2011.

60. Nilima Choudhury, "Research Council of Oman to Fund Renewable Energy Studies," *pv-tech.org News*, January 10, 2012, available at: http://www.pv-tech.org/news/research_council_of_oman_

In fact, a close look at the multiple activities conducted in the RE field by universities and colleges, governmental bodies and ministries, companies or the Oman-based Middle East Desalination Research Center[61] shows that for this expertise to take root in the country, creating links between the various Omani policy-making, educational, industrial, and/or R&D institutions is key.

From the public and private higher education side, SQU or Dhofar University had launched numerous projects integrating clean technologies through academic programs or in students' course tasks, thus giving their graduates general technical knowledge in the fields of renewable energies, their materials, devices and systems, as well as design aspects of related projects; Furthermore, in addition to RE potential GIS assessment, the result of which we have described earlier, research has been conducted by different SQU colleges and departments [62] to cover solar energy systems and applications, solar cooling and heating, solar water desalination, or solar crop drying. More particularly, the Renewable & Sustainable Energies Research Group (RASERG), based at SQU College of Engineering,[63] has been compiling and analyzing solar performance data of a 12 MWh/year concentrated photovoltaic (CPV) experimental plant since May 2010. Set up in the Knowledge Oasis in Muscat, the demonstration project uses Gallium Arsenide triple junction wafers and a double-tracking system to achieve an efficiency of 32 percent. Such a result is remarkably high, and it is expected that the CPV research facility will be expanded to include a water purification system by September 2011.[64] However, as ought to

to_fund_renewable_energy_studies ; *Times of Oman*, "Call to Tap Solar Energy to Meet Power Demands in Oman," January 11, 2012;

61. As part of a project on the application of solar energy in RO water desalination, Middle East Desalination Research Center (MEDRC) and the Caledonian College of Engineering (located in Seeb, Oman) launched feasibility studies for the application of photo-catalytic mechanisms in RO pre-treatment. A permanent headquarters building of MEDRC in Oman is planned near SQU-Water Research Center, to "start strategic cooperation between the Center and the University and strengthen applied research facilities in Oman." See http://www.medrc.org/index.cfm?area=about&page=Institue_Overview

62. College of Engineering, College of Science, College of Agriculture & Marine Sciences, College of Art and Social Sciences.

63. The Renewable & Sustainable Energies Research Group (RASERG) was established in 2003 to provide research and consultancy services to the industry and the scientific community in the field of renewable and sustainable energies. This includes PV System, eco-building, solar thermal system, energy planning and management, wind energy system, and GIS-based investigation of RE potential location process. See http://raserg.ren-oman.net

64. For this, RASERG collaborates with Oman's ABS Advanced Business Solutions and Germany's Azur Space Solar Power GmbH and Concentrix Solar GmbH. See http://abs-oman.com/news.html

be the case in all GCC countries, such R&D activities should be linked to potential industrial applications in the country. For graduates as for researchers, when technical knowledge is not put into practice in the five to 10 years following its acquisition, it simply becomes obsolete; hence the recurrent recourse to foreign expertise.

Phoenix Solar L.L.C, a newly founded photovoltaic system integrator company based in Oman,[65] was appointed by the Saudi Arabian oil company ARAMCO to design and build a grid-connected ground-mounted photovoltaic plant in Riyadh with a peak power of 3.5 megawatts. A determinant factor for winning the contract was said to be the experience gathered by Phoenix Solar from a photovoltaic testing field that ARAMCO commissioned it to install in 2010 to analyze different module technologies at its headquarters in Dhahran.[66] As an Oman-based company, how much of this knowledge and experience is transferred to academics, engineers or technicians in Oman?

The Research Council's future program on RE development may have to tackle the isolated nature of RE R&D efforts in the different Omani institutions, or overcome the fact that so far these efforts remain unrelated to the Sultanate's actual energy context. However, beyond networks, the capacity building objectives of such a plan cannot be reached without widespread utilization of RE technologies; consequently, with such objectives in mind, Omani authorities need to facilitate the implementation of RE projects through appropriate energy and manufacturing policies and legal and financial frameworks that help attract investments.

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and Hannah Uckat, "Market Overview and Update: Renewable Energy and Energy Efficiency in Oman."

65. Phoenix Solar LLC in Oman is a subsidiary of Phoenix Solar AG, an international photovoltaic system integrator; Phoenix Solar AG, the founder, holds 70 percent and Silver Circle Overseas L.L.C. (SCO) – its local partner in Oman – 30 percent in Phoenix Solar L.L.C. With its headquarters in Muscat, Silver Circle Overseas L.L.C. invests in the areas of project development, renewable energies and various industrial sectors. The company was founded in 2005 and has been closely following the issue of renewable energies in Oman since 2006. In cooperation with COWI A/S, a Danish company, Silver Circle Overseas L.L.C. completed a study for the local regulatory authority AER in 2008 titled *Study on Renewable Energy Resource*. Since then, solar energy has developed into one of the company's focal areas. www.phoenixsolar.com and http://silvercirclegroup.net/Default.aspx?tabid=36; also "Oman's Phoenix Solar to Build Solar Park for Saudi Aramco," *Oman Daily Observer*, February 16, 2011 available at http://omanobserver.om/files/pdf/2011/2/16/OmanObserver_16-02-11.pdf

66. Reuters, "Phoenix Solar AG to Build Solar Power Plant for Saudi Arabian Oil Company in Riyadh," February 14, 2011 available at: http://www.reuters.com/finance/stocks/PS4G.DE/key-developments/article/2085844

Towards Public-Private Partnerships in RE

Interestingly, almost in parallel with the Research Council announcement, foreign investors and the private sector in Oman showed increasing interest in the solar energy potential of the Sultanate. In mid-January 2012, the Swiss-licensed global wealth management company Terra Nex Financial Engineering AG announced that, in collaboration with the German 'Middle East Best Select (MEBS) Group of Funds,' it planned to invest $2 billion to develop PV solar power in the Sultanate, including silicon production, solar panel and aluminum frame manufacturing, a 400MW solar power plant, as well as related education and training programs in RE for the local workforce. For this purpose, Terra Nex and MEBS launched an Oman-centered renewable energy private investment fund "Solar Energy-Photovoltaik in Oman" for its German investors, in which MEBS will invest $200 million to finance the first solar power station and Siemens AG will serve as a technology partner for the project. [67]

Such a comprehensive plan, which is expected to produce 120 MW of solar panels a year and create over 2,000 direct and indirect job opportunities in Oman, [68] has naturally gathered interest from different governmental bodies such as the Public Authority for Investment Promotion & Export Development (PAIPED), the Special Economic Zone at Duqum, the PAEW, or Oman Power and Water Procurement Company (OPWPC). However, with international and local private actors showing interest in investing in the whole value chain of the RE sector, Omani authorities need to think of a broad framework which will make these investments viable and sustainable at all levels; such a framework should encompass electrification of rural areas, technology transfer, human development, market supply and demand, and protection of the environment.

Increasing production costs of oil and the scarcity of gas resources in Oman

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67. Of the $2 billion necessary for the project, Terra Nex expects $600 million to be direct equity capital and the remaining to be covered by loans from European financiers; It was also announced that Terra Nex and MEBS have agreed with Shaikh Hilal bin Khalid bin Nasser Al-Maawali, local partner of Terra Nex and MEBS, to offer 40 per cent of the capital for public subscription in the future after not more than four years from the start of the operation of the project. See Faizul Haque, "Terra Nex, MEBS Plan $2b Solar Energy Project," *Oman Tribune*, January 2012; "Terra Nex Plans to Build 400 MW PV Facilities in Oman," *Solar Server*, http://www.solarserver.com/solar-magazine/solar-news/current/2012/kw03/terra-nex-plans-to-build-400-mw-pv-production-facility-in-oman.html ; and Times of Oman, "German Investors Eye Solar Energy Projects," January 15, 2012.

68. A. E. James,"Value Chain In Solar Industry Planned," *Times of Oman*, January 12, 2012.

are strong drivers for the government to both rationalize its energy consumption and champion renewable energy sources. Strategic imperatives for the Sultanate's energy sector are about balance of trade in natural gas. LNG exports are important for the country's economy, but growing domestic electricity consumption means that it has to import increasing amounts of natural gas. The solution resides in disseminating solar- and wind-based electricity generation systems, as demonstration and feasibility studies have proven their viabilities.

With the 200MW solar plant due by 2013, and the announced 400MW PV station by Terra Nex, the cumulative RE capacity would represent 8.2 percent of the projected peak demand in Oman by 2016. If such projects are implemented, then the Sultanate would logically be moving towards its target to produce 10 percent of its energy needs from RE sources by 2020. The rapid implementation of the remote RE pilot plants would further confirm such outlook.

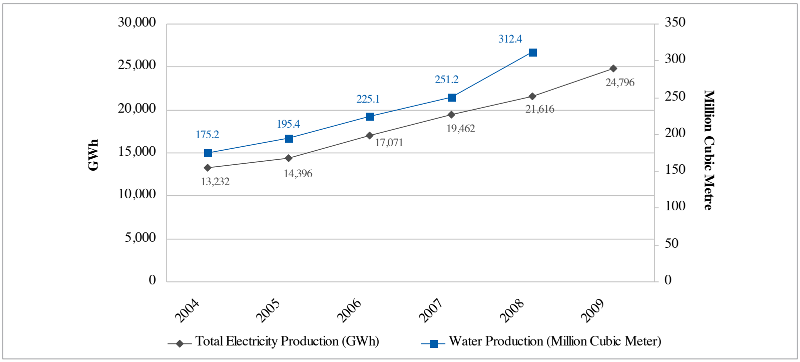
Chapter Four

Qatar

Electricity Surplus and Export Prospects

Qatar is among the fastest growing power markets in the GCC. Demand for power has increased sharply in the last few years while production capacity reached 8,000 megawatts in July 2011. About 5,300 MW was consumed during peak loads, leaving a comfortable electricity surplus of 2,700 megawatts – the largest reserve margin in the region – for the country to cater for its own socio-economic expansion and to export to other GCC countries through the GCC Interconnection Grid.

Growth in Electricity and Water Consumption - Qatar

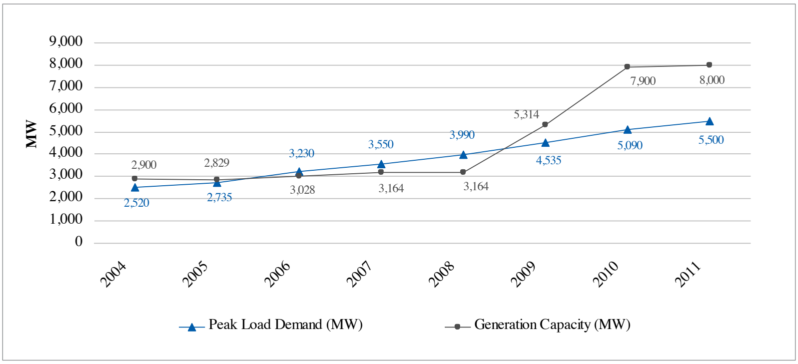


Production of electricity and water has been growing at a very fast pace in Qatar (80% in the past five years).

Source: Based on IEA's *Energy Statistics of Non-OECD Countries*, 2011 Edition for Total Electricity Production (GWh); and on KAHRAMAA, *Statistics Report 2008* for Water Production (million cubic meter)

Since then, demand has peaked at 5,500 MW for the year 2011, up from 5,090 MW in the previous year. In general, the peak load has increased at an average annual growth rate of 10.7 percent for the last seven years. Installed generating capacity stood at 1,800 MW in 2000, a figure that reached 5,314 MW in 2009 and expanded to 8,000 MW in 2011, thus registering an average annual growth rate of 31.3 percent between 2000 and 2011. Qatar's electricity reserve capacity was around 15 percent in 2009.[1] It reached 33 percent in 2011, thus exceeding industrial recommendations of a constant reserve margin of 10 to 20 percent of total capacity.

Qatar - Electricity Capacity and Peak Load 2004 - 2011



Between 2008 and 2010, Qatar's generation capacity has expanded dramatically at an annual growth rate of 70% to a level that exceeds that required by the country's peak load demand. The electricity surplus is exported to other GCC countries through the GCC Interconnection Grid.
Source: Based on Electricity Statistics from KAHRAMAA, *Statistics Report 2008*; US Energy Information Administration; and MEED Power Reports

Taking advantage of this surplus and the time difference between some GCC countries, Qatar exported some of its electricity surplus on a commercial basis during the summer of 2011 and provided the GCC Interconnection Grid with about 200 megawatts through its main network.[2] The GCC Interconnection Grid, formed in

1. Digby Lidstone, "GCC Power: Harnessing the Elements," *MEED*, March 2010, available at http://www.meed.com/supplements/2010/gcc-power-market-report-2010/gcc-power-harnessing-the-elements/3005249.article; and "Doha's Power Sector Enters the Comfort Zone," *Middle East Power Survey*, *MEED* Supplements, 2010; article available at: http://www.meed.com/supplements/2010/middle-east-power-survey/dohas-power-sector-enters-the-comfort-zone/3073360.article
2. Engineer Issa Hilal Al Kuwari, President of Qatar General Electricity and Water Corporation, says Qatar's production of electrical power amounts to 8,000 megawatts; Original article in Arabic:

2010 by connecting the national grids of Saudi Arabia, Qatar, Kuwait and Bahrain, now enables electricity trading between these countries. Saudi Arabia-based Gulf Cooperation Council Interconnection Authority (GCCIA) is the body that regulates such exports and determines the beneficiary country.

Up to 1999, all electrical power generation, water production, and transmission and distribution services in Qatar were carried out by the Ministry of Electricity and Water (MEW). In 2000, the Qatar government adopted a deregulation strategy and encouraged the privatization of the electricity generation and water production services. This led to the establishment of the Qatar Electricity and Water Corporation (QEWC) and other Independent Power and Water Providers (IPWP), giving private investors and international developers a major role in building up significant generating capacity in the country. Public-Private Partnership (PPP), which is encouraged and extensively used, is now the established model for procuring new electricity and desalination capacity in Qatar.[3]

After the dissolution of the Ministry of Electricity and Water, responsibility for the transmission and distribution of electricity and water was given to the power and water distribution company Qatar General Electricity and Water Corporation or KAHRAMAA. It is the single and exclusive owner and operator of the transmission and distribution network systems and is responsible for the forecasting of related national demand and defining requirements for electricity and water infrastructure. As such, it purchases power under long-term purchase agreements from Independent Water and Power Projects (IWPP) developers and is extensively involved in negotiating with them for the construction of additional power stations and desalination plants to meet demand.[4]

KAHRAMAA also has the task of implementing new projects. Since 2007, several projects were planned to further the capacity of important power and water plants. As Eng. Issa Hilal Al Kuwari, President of KAHRAMAA stated, Qatar will continue expanding the electricity and water services without a decrease in production or major breakdowns in the network.[5] However, the frenetic socio-

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“8 آلاف ميغاوات إنتاج قطر من الطاقة الكهربائية”, Qatari News Agency (QNA), July 27, 2011.

3. Ed James, “Embracing Public-Private Schemes in Qatar,” Qatar Projects, *MEED* Supplement (2011).

4. KAHRAMAA, *Statistics Report 2008*.

5. List of KAHRAMAA’s key projects in KAHRAMMA, *Statistics Report 2008*; table EW2, p.12. Al Kuwari’s statement in “Qatar’s Production of Electrical Power Amounts to 8,000 megawatts,” see note 2. According to Salah Hamza, senior business development planner at KAHRAMAA, Qatar expects to add 16,260 MW of power to the national grid between 2011 and 2036, almost

economic growth and resultant increasing energy consumption that is currently taking place in Qatar will exert much pressure on authorities to prepare for an average 1,000 MW additional capacity every year, in order to match demand.

Water Stress

Studies indicate that Qatar is facing water stress and has a number of challenges to maintain continuous supply and accommodate growing needs. A large portion of the country's water goes to the agricultural sector, but increasing demand is due to the growing urban population and industrial expansion. Indeed, domestic and industrial water needs are primarily met through desalination; Qatar's production capacity has more than doubled since 2004, at an average growth rate of 15 percent annually. However, despite the production increase, the rate of water use per capita has been growing in recent years, leading to rising water stress.[6] Currently, desalination accounts for about half the total water used in Qatar and 99 percent of its drinking water. It is expected that water production will rise by 9 percent between 2011 and 2015.[7]

According to the Food and Agriculture Organization (FAO), seawater intrusion is a severe problem along the coast of the country due to the high permeability of the fractured limestone aquifer containing freshwater. Together with its rapid socio-economic development, Qatar's scarcity of water resources, incorrect agricultural practices, excessive pumping and pollution (excessive salinity) of groundwater will cause desertification and consequently increase reliance on sea water desalination in the future.[8]

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four times the electricity capacity of 4.2 GW in 2008; Reuters, February 2, 2008.

6. Food and Agriculture Organization (FAO), *Qatar Water Report 2009* available at http://www.fao.org/nr/water/aquastat/countries/qatar/index.stm ; Qatar General Secretariat for Development Planning, *Qatar National Development Strategy 2011-2016*, 81-82 and 217-218; KAHRAMAA *Statistics Report 2008*; and "Qatar: Development Taking a Toll on Water – Study," *The Peninsula*, September 2, 2011.
7. Desalination accounts for about half the total water used in Qatar, fresh groundwater drawn from natural aquifers accounts for about 36 percent of the water used in Qatar; and recycled water, or treated sewage effluents, account for the remaining 14 percent. See *Qatar National Development Strategy 2011-2016*, 217-218; Forecasts for 2011-2015 water production in *Business Monitor International*, "Qatar Water Report," April 2011 available at http://www.marketresearch.com/Business-Monitor-International-v304/Qatar-Water-Q2-6230942/
8. FAO, *Qatar Water Report 2009*.

Qatar's desalinated water is currently produced by means of energy-intensive thermal desalination processes (mainly MSF). Such technology claims vast areas of land which, in the case of Qatar, limits future capacity expansion. It also affects the environment, augmenting seawater salinity on the west coast, which together with the lack of space in the heavily populated east coast cause substantial constraints for the water sector.

Against this backdrop, Qatar Electricity & Water Company (QEWC), the largest power and water producer in Qatar,[9] has established a research and development facility in collaboration with Water Re-Use Promotion Center (WRPC) of Japan. The R&D activities, based in Dukhan, include studying the feasibility of new water desalination technologies – based on seawater Reverse Osmosis – as these do not consume as much power and can tolerate higher salinity levels than current processes. It is worth mentioning that in 2006 WRPC signed a research agreement with the Saudi Saline Water Conversion Corporation (SWCC) to develop a tri-hybrid nano-filtration/reverse osmosis/multi-stage flash (NF/RO/MSF) technology system, with the aim of commercializing the technology for future desalination projects.[10]

Mounting Gas Consumption

Qatar is wholly dependent on oil and natural gas for all of its primary energy consumption. As well as being an important natural gas producer, the country is an intensive consumer of gas, which accounted for almost 80 per cent of its

9. QEWC is a publicly listed joint stock company that is 43 per cent owned by the government and 57 percent by public and private firms or individuals. QEWC's assets are divided between full ownership of plants acquired either from the Electricity & Water Ministry, or its successor KAHRAMAA, and equity stakes in IWPPs, including the recently-inaugurated Mesaieed IPP with the capacity of 2,000 MW to serve the national grid and the proposed Mesaieed aluminum smelter. The plant is owned by the Mesaieed Power Company Ltd. where the main shareholders are QEWC with 40 percent, Qatar Petroleum (QP) with 20 percent and Marubeni Corporation of Japan with 30 percent. See "Emir of Qatar Inaugurates the Mesaieed Power Plant Today" (in Arabic)أمير قطر يدشن محطة مسيعيد للكهرباء اليوم ; *Al Raya* (Qatar), May 18, 2010 and homepage of Zawya projects, May 24, 2010: http://www.zawya.com; QEWC information in: http://www.qewc.com/Web.nsf/index?OpenPage and in Elizabeth Bains, "Qatar Electricity & Water Company," *MEED*, March 2009, available at: http://www.meed.com/supplements/qatar-electricity-and-water-company/3000241.article#ixzz1X3yuuMZE

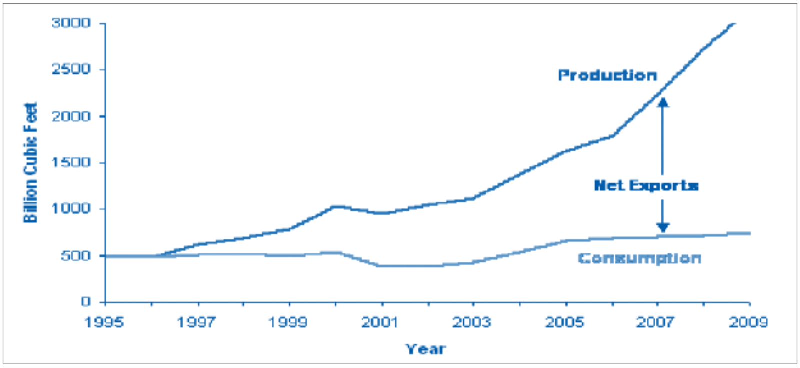
10. Qatar General Secretariat for Development Planning, *Qatar National Development Strategy 2011-2016,* 81 and 217; and "New Desalination Techniques," in *MEED*, October 13, 2006, available at http://www.meed.com/sectors/power/new-desal-techniques/238505.article

primary energy demand in 2008.[11] In 2009, it consumed almost 25 percent of its gas production for the same year.

However, as Qatar's domestic gas consumption continued to grow, the country increased its production in order not only to fuel its expanding domestic industry and its gas-to-liquids (GTL) projects, but also to satisfy Liquefied Natural Gas (LNG) exports. As per 2009 statistics, of the 2,400 Bcf of natural gas exported by Qatar, 30.4 percent (about 2 Bcf/d) was sent to the UAE and Oman through the Dolphin pipeline.

Overall, Qatar's focus on natural gas development has centered on integrated large-scale projects linked to LNG exports or downstream industries that utilize natural gas as a feedstock. However, prompted by worries about the health of the North Field reservoir, the authorities imposed a moratorium on further gas projects in 2005. [12]

Qatar's Natural Gas Production and Consumption, 1995 - 2009



Thanks to accelerated growth in production, Qatar has built up an ever-expanding surplus of gas, which feeds its balance of trade.
Source:EIA

In parallel with the transportation sector's growing need for oil, Qatar's electricity sector continues to contribute significantly to growth in gas demand in

11. Digby Lidstone, "Doha Considers Power Exports," GCC Power 2010, meed.com, 2010.

12. In 2009, 70 percent of Qatar's gas exports were liquefied natural gas (LNG). Dolphin Energy has been trying to secure additional Qatari gas especially to meet rapidly growing demand of the UAE; however, according to US Energy Information Administration (EIA), increased supplies from Qatar are uncertain. See *Qatar Analysis Brief*, http://205.254.135.24/countries/cab.cfm?fips=QA, and Lidstone, "Doha Considers Power Exports."

the country. Indeed, all of the electricity and desalination facilities of QEWC and IPWPs are gas-fired, and the only source of their fuel supplies is the state-owned Qatar Petroleum (QP).[13]

The announcement of the North Field moratorium coincided with the surge in electricity demand from 2005 onward; six years later, KAHRAMAA and QEWC have not yet implemented energy projects based on alternative sources.[14] The moratorium does not seem to have affected the expansion of the electricity and water production capacity in Qatar. Actually, by the end of 2011, Qatar's total power capacity should reach 9,039 MW and its desalination capacity 242 MIGD (million imperial gallons per day).[15] Moreover, according to the country's 2011-2016 national development strategy, one of the possibilities for Qatar to leverage its cheap domestic feedstock and energy to contribute to long-term economic diversification and the expansion of the productive base could be for the country to export surplus power generated from gas to the region and beyond, wherever the right infrastructure allows it.[16]

However, as mentioned earlier, Qatar needs to find a focal point for its industrial development, as its energy and industry are closely connected sectors. Besides the North Field moratorium on gas allocation[17] and Qatar's long-term commitments for gas exports, the increasing local peak demand – expected to be around 7,791 MW by 2013 – and the sustainability imperative of the country's strategic industrial choices should add to the conflicting challenge of gas availability for electricity and water production processes; indeed, these already use large amounts of this feedstock. Hence, firing even more gas to generate electricity for exports can impede the country's potential advantage in the area of processing, transportation, distribution and storage of liquefied natural gas, besides the incurred environmental

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13. US Energy Information Agency, *Qatar Analysis Brief*; and KAHRAMAA, *Statistics Report 2008*, 10.

14. W.E. Alnaser and N.W. Alnaser, "The Status of Renewable Energy in the GCC Countries," *Renewable and Sustainable Energy Review* 15 (2011): 3074-3098, 3094.

15. Projections for water production from *MEED* article on http://www.meed.com/sectors/power/power-generation/qatar-inaugurates-countrys-largest-power-and-water-project/3099814.article;

16. This is justified by the fact that "high-voltage direct-current cables lose very little energy in long-distance transmission – about 3 percent per 1,000 kilometres – perform efficiently under water, and hence could be an option." See *Qatar National Development Strategy 2011-2016*, 73.

17. The moratorium on these allocations from the North Field is unlikely to be lifted before 2012-13. See Elizabeth Bains, "Qatar Electricity & Water Company," *MEED*, March 2009, available at: http://www.meed.com/supplements/qatar-electricity-and-water-company/3000241.article#ixzz1X3yuuMZE

impact.[18] All these factors, however, should motivate the designing of policies that promote the rational use of the country's cheap energy as well as clean development schemes – like the deployment of renewable energy technologies – to protect the environment.

Pressure on the Environment

Rapidly growing population and expansion in the energy and industrial sectors increased greenhouse gas and carbon dioxide emissions – mostly from energy production – and contributed to local pollution and global climate change. In fact, global climate change poses special challenges as Qatar, being a small coastal country, is vulnerable to predicted rising sea levels. Furthermore, environmental stress in Qatar also points to:

- A rising water table in Doha multiplying the city's environmental challenges
- Increasing salinity in groundwater sources for agriculture
- Declining air quality that contributes to high rates of asthma and respiratory illnesses.[19]

In 2005, Qatar was ranked 58th globally in total carbon emissions but first in per capita carbon emissions. Because of its high emitting gas production sector and small population, Qatar's per capita carbon emissions are excessive.[20]

According to the International Energy Agency (IEA) statistics for the year 2009, the major contributor to Qatar's CO_2 emissions is the oil and gas sector, with upstream and downstream operations accounting for up to 67 percent of the total. The third biggest emitter, however, is the electricity and water production sector, which contributed 22 percent of the total CO_2 emissions.[21]

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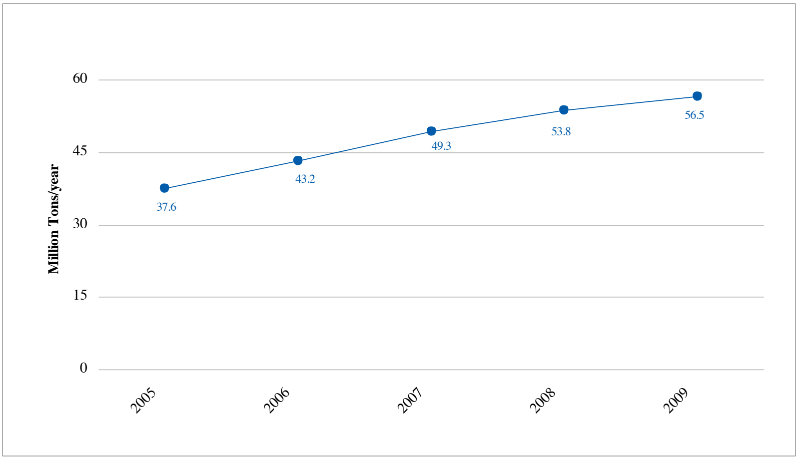
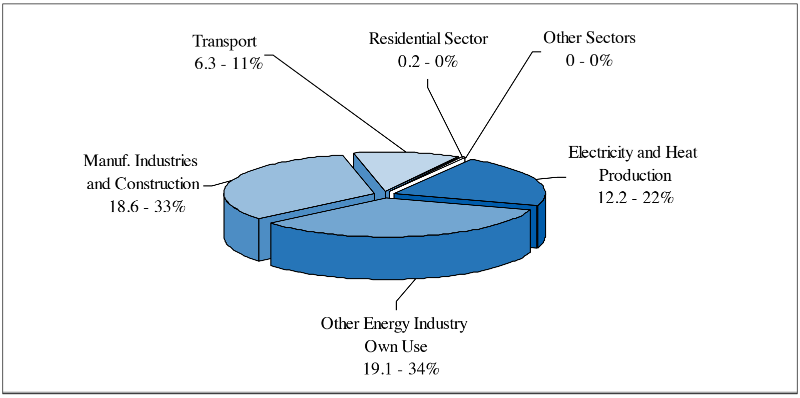
18. It is argued that investments in liquefied natural gas projects will remain relatively strong over the medium term, amounting to about QR 88 billion during 2011-2016. These investments include plans for about QR 7 billion in expanded capacity of Qatar's petrochemical sector, including production of low-density polyethylene, ammonia and urea. See *Qatar National Development Strategy 2011-2016*, 71.
19. *Qatar National Development Strategy 2011-2016*, 214-215.
20. Global ranking for total and per capita carbon emissions are from *Qatar National Development Strategy 2011-2016* citing *Carbon Dioxide Emissions 2005*; 223, Table 6.2 ; also see Ameinfo, "Combating Qatar's CO2 emissions, Carbon World 2009 Addresses Reduction," http://www.ameinfo.com/181812.html and *The Peninsula*, "Carbon Dioxide Emissions in Qatar 'Modest'," available at: http://www.gulfbase.com/site/interface/newsarchivedetails.aspx?n=103475)
21. IEA, *CO_2 Highlights* (2011).

Qatar CO_2 Emissions 2005 - 2009



Source: Based on IEA, *CO2 Highlights* (2011)

Qatar CO_2 Emissions from Fuel Combustion in 2009 by Sector (million tons)



In the past five years, Qatar's CO_2 emissions have steadily increased at a rate of 12.5% per annum. More than two thirds of Qatar's CO_2 emissions originate from industrial uses, especially from the oil and gas sectors.
Source: Based on IEA,*CO2 Highlights* (2011)

The environmental impact of the power and water sectors is also exacerbated by huge inefficiencies, prompting the authorities to opt for the right set of technologies and policies. For instance, losses in the desalinated water network, which amounted to 30 percent of the total production in 2008 (312 million cubic meters), will be lowered to only 10 percent by 2016, hence saving as much as QR1 billion a year. Similarly, KAHRAMAA recognizes the need to improve efficiency in the power production and transmission sector where technical enhancement could enable gas savings of about 2 percent of estimated local demand by 2016.[22] It may be hoped that such savings will be invested in the deployment of RE technologies.

At any rate, for a sustainable socio-economic expansion, Qatar needs to promote clean technologies and environmentally sound practices. In particular, demand side management and energy efficiency technologies should cut down power demand and yield benefits for the protection of the environment. For instance, not only will reduced water losses mitigate the rising water table in Doha, it will also support Qatar's national goal of reducing carbon dioxide emissions that are record high. Similarly, given the fact that air conditioning accounts for almost 67 percent of residential power consumption, a wider use of energy efficient appliances, or district cooling,[23] should help reduce power demand and protect the environment. In addition to electricity and water demand management, better insulation or increased shading for the built environment that integrate RE – especially photovoltaic cells – onto the structure can play an important role in achieving energy-efficient buildings.

More generally, renewable energy systems are clean sources of energy and their positive impact on Qatar's environment should be taken into consideration.

Potential of Renewable Energy Sources (RES)

Solar Energy

Qatar has an arid desert climate that is characterized by high temperatures exceeding 40°C during summer, scanty rainfall, very strong winds, high evaporation rates, and relative humidity. Extensive meteorological data has been collected by the Department of Meteorology at Qatar's Ministry of Communication and Transport since 1972 which have helped in estimating solar and wind energy parameters.

The availability of solar and wind energy in Qatar has been evaluated in many

22. *Qatar National Development Strategy 2011-2016*, 80-84 and 220-221.

23. Some major district cooling service providers were developed and contracts were expanded in Qatar. See H. Doukas, K. D. Patlitzianas, A. G. Kagiannas, and J. Psarras, "Renewable Energy Sources and Rational Use of Energy Development in the Countries of the GCC: Myth or Reality," *Renewable Energy* 31 (2006): 755-770, 764.

studies, and results suggest that the adoption of solar and wind technologies could be beneficial for the country. As is the case for the whole region, solar radiation is available in abundance in Qatar, where the Global Horizontal Irradiance (GHI) – useful for photovoltaic systems – averages 5.5 $KWh/m^2/day$ or 2140 $KWh/m^2/year$ and the average Direct Normal Irradiance (DNI) – for Concentrating Solar Power systems (CSP) – is 5.6 $KWh/m^2/day$, or 2000$KWh/m^2/year$.[24]

Economic analyses of electricity generation using photovoltaic (PV) or CSP systems have been conducted for Qatar.[25] A short study comparing the electricity generation cost per KWh of a conventional gas-turbine system and that of a 100 MW PV station has concluded that the latter was 2.25 times higher than the former; the cost of PV solar electricity was found to be $0.121/KWh and that of gas-generated electricity $0.0537/KWh. According to the study's author, this basic economic evaluation suggests that PV technology is far from being economically feasible for Qatar. A wide market demand for, and improved technology performance of PV systems should result in improved conversion efficiency and lower unit cost, which would make the PV generation cost competitive with that of a gas turbine.[26]

According to a German Aerospace Center (DLR) study, CSP technology is among the most suitable solar energy technologies to fulfill the electricity needs of the GCC countries. Indeed, this study estimated the technical and economic potentials for such systems in Qatar and found that for sites with DNI bigger than 2,000KWh/year solar electricity supply can reach 792 TWh/year.[27] In fact, this figure is 36 times the electricity actually generated in Qatar in 2008 which then reached 21.6 TWh.

Wind Energy

According to Al Naser and Al Mohanadi, the yearly average wind power density in Qatar is 59W/m^2, with the highest densities occurring between March and June corresponding to the highest monthly wind speeds recorded. In general, it was observed that the annual average wind speed in Qatar is 4.58 m/s at 10 m height

24. W. E. Alnaser and N. W. Alnaser: "Solar and Wind Energy Potential in GCC Countries and Some Related Projects," in *Journal of Renewable and Sustainable Energy* 1 (2009); and the German Aerospace Center (DLR) study on *Concentrating Solar Power for the Mediterranean Region* (April 2005), 57.
25. A. H. Marafia, "Feasibility Study of Photovoltaic Technology in Qatar," *Renewable Energy* 24 (2001); German Aerospace Center (DLR), *Concentrating Solar Power*.
26. Marafia, "Feasibility Study of Photovoltaic Technology in Qatar," 567.
27. German Aerospace Center (DLR), *Concentrating Solar Power*.

and that wind direction is mainly north to north-west over the year.[28]

In fact, with 1,421 full load hours of wind per year, onshore or offshore areas with such a capacity factor (16 percent) could represent long-term economic wind potential for Qatar and play a role in power generation diversification.[29] Indeed, an assessment of the technical and economic potentials of wind energy in Qatar was conducted based on long-term measured onshore wind speed (data collected from 1976–2000) at Doha and offshore wind speed at the Qatari Haloul Island. The comparative analyses – which took into consideration the interest recovery factor, the lifetime of the wind energy conversion system, plant productivity, investment rate, and operation and maintenance costs – indicated that the cost of electricity generation from wind at both sites compares favorably to that from gas-fired turbines:

a) Onshore wind electricity cost at Doha was 8 percent less than the gas-generated electricity cost

b) Generation cost from a wind turbine installed in Haloul was about 10 percent less than the cost of generation from a gas turbine and 8 percent less than that of the onshore Doha wind site.

Furthermore, the study concluded that the establishment of wind farms on islands like Haloul – with means to transfer generated electricity to the nearby onshore areas – is expected to be both technically feasible and economically viable.[30] Nevertheless, according to other assessment studies, it is important to do more research, in collaboration with international databases, to produce a more accurate picture of the wind atlas in the territorial waters of Qatar.[31]

Industry-University Linkages and R&D

The importance of conducting research and development (R&D) studies related to energy and local environmental issues has been gradually recognized by Qatar's industrial and educational institutions. Further to the renewable energy assessment

28. W. E. Alnaser and A. H. Almohanadi, "Wind and Solar Energy in Qatar," *Energy* 15 (1990): 931-934.

29. German Aerospace Center (DLR), *Concentrating Solar Power*, 68

30. A. H. Marafia, H A. Ashour, "Economics of Off-shore/On-shore Wind Energy Systems in Qatar," *Renewable Energy* 28 (2003): 1953-1963; Doukas, Patlizianas, Kagiannas and Psarras, "Renewable Energy Sources and Rational Use of Energy Development," 565-567.

31. For studies on offshore wind potential in the Gulf waters, see Ali Mostafaeipour, "Feasibility Study of Offshore Wind Turbine Installation in Iran Compared with the World," *Renewable and Sustainable Energy Reviews* 14 (2010): 1722–1743.

research that has been conducted in the country since the 1990s, the Qatar National Research Fund (QNRF), a member of the Qatar Foundation, has recently funded collaborative research proposals in the field of solar energy and environment as part of the National Priorities Research Program (NPRP). These research projects involved Qatar National Cement Company, Qatar University, Texas A&M University, and others and addressed topics like solar sea water desalination systems or Photovoltaic panels and their grid integration.[32]

More recently, Qatar University and the German-based company Heliocentris Energy Solutions agreed to establish a teaching laboratory in the university to provide practical knowledge in the fields of solar and wind energy generation systems and storage, including fuel cells and hydrogen technology. The Heliocentris modeling system would be used to simulate an autonomous hybrid energy system for the university.[33]

Similarly, Qatar Environment & Energy Research Institute (QEERI), a member of Qatar Foundation, has signed an agreement with the Spanish Research Centre for Energy, Environment and Technology (CIEMAT) to develop solar technology research capacity for the region. The two institutions will jointly study the feasibility of implementing a CSP desalination pilot project of 300KW.

Qatar aspires to diversify its industries and enhance the knowledge and science base of its economy. Through its Science and Technology Park (QSTP), the country supports international companies, institutes and entrepreneurs to develop progressive technologies in Qatar and enhance their partnership with the universities based in Education City. Such an approach is intended to promote linkages between research and commercialization of the companies' technologies. In addition to research fields like medicine and Information Technologies (IT), special emphasis is put on innovation in renewable energies and environmental technologies. As a result, local and international universities, like Qatar University or Texas A&M University, have implemented related teaching and research programs. [34] For instance, a joint research program agreement has been signed between QSTP and Germany's Fraunhofer Institute to produce hydrogen from solar energy. The applied research project entitled "Solar Carbon Black Project" is co-financed by QSTP and the Federal State of Sachsen and also involves Texas

32. More information on QNRF-NPRP funding program and its awarded grants can be found at: http://www.qnrf.org/funding_programs/nprp/index.php

33. http://www.renewableenergyfocus.com/view/21233/heliocentris-wins-energy-lab-order-in-qatar-expands-middle-east-presence/

34. http://www.kooperation-international.de/countries/energie/international/clusterlist/cluster-qatar/

A&M and Qatar University with the objective of developing a reactor for solar thermal applications.[35]

In February 2009, Chevron Corporation and QSTP announced that they will establish the Chevron Center for Sustainable Energy Efficiency (CCSEE) to research the development and application of low-energy lighting technologies, solar cooling (air-conditioning) and solar panels adapted to the Middle East's climate. Chevron plans to invest $20 million over five years to fund the center. According to the Research Manager of CCSEE, the center will collaborate with universities in Education City, QSTP tenants, and local developers to train young Qatari engineers, scientists, and students to build up their technical expertise and capabilities.[36]

In this regard, partnering with QSTP and Chevron Qatar Energy Technology,[37] Green Gulf Incorporated – a QSTP-based renewable energy and clean technology company – agreed in March 2009 to establish an experimental facility to study different solar-to-electricity conversion methods.[38] In the first phase of the project, the performance of photovoltaic and solar-thermal electricity generation technologies will be tested under Qatar's particular environmental conditions of dust, heat and humidity. The venture then aims to establish a 500 kW/35,000 m^2 pilot plant at QSTP using the most appropriate technology which would supply electricity to Education City.[39]

Such public-private partnerships (PPP), bringing together industrial technical expertise, science investment, and higher education, are welcomed by QSTP officials and tenants as essential for R&D projects to be successful and RE innovations commercialized. Solar energy, it is argued, is one of the strategic areas where QSTP

35. Homepage of Saxony: http://www.sk.sachsen.de/18553.htm and Qatar News Agency, "Qatar Foundation: Sheikha Mozah Witnesses Solar Carbon Black Project Agreement," in Global Arab Network, October 2010, available at: http://www.english.globalarabnetwork.com/201009307485/Energy/qatar-foundation-sheikha-mozah-witnesses-solar-carbon-black-project-agreement.html

36. See QSTP website at: http://www.qstp.org.qa/output/Page2220.asp; Mike Farshchi, Research Manager of Chevron's Center for Sustainable Energy Efficiency at Qatar Science and Technology Park, on Chevron website: www.chevron.com

37. Chevron Qatar Energy Technology is an affiliate of Chevron Corporation.

38. Under the Memorandum of Understanding, Chevron and Green Gulf should each invest up to $10 million in this R&D program; technology tests commence in late 2010 and continue for two to four years.

39. See http://www.green-gulf.com/en/media_press_18-03-09.php , QSTP website at: http://www.qstp.org.qa/output/page2236.asp and http://www.ameinfo.com/230640.html

can make the most impact and where Qatar can achieve its goal of becoming a post carbon economy.[40]

With this in mind, QSTP is also championing the Qatar Advanced Biofuel Platform, an ambitious Biomass-to-Liquid (BTL) collaborative research project across the aviation and energy industries which involves: [41]

– An engineering plan for "economically viable and sustainable biofuel production"

– A biofuel investment strategy

– An advanced technology development program

– Market and strategic analysis

Based on Qatar's plan to protect the environment and its concer ns about hydrocarbons and water sustainability, the initiative to develop aviation biofuels is led by Qatar Airways, Airbus, and Qatar Petroleum. A detailed implementation plan for biofuel production, an investment strategy plan, and market analysis are being developed for this project. It has not been specified which feedstock should be considered for use in the Qatar project. However, it was emphasized that feedstock growth would have no effect on the food chain or water supply. Following Airbus's classification of potential locations for biofuel feedstock growth, prospects for Qatar and the Gulf region indicate that algae would be most suitable for such lands. Airbus expects that cooperation within this industry-wide Qatar Advanced Biofuel Platform will achieve real progress in finding sustainable jet fuel alternatives and speeding up their commercialization. Incidentally, Airbus's forecasts put at around 30 percent the share of biofuels in all jet fuel used by 2030.[42]

For QSTP, such research activities on alternative and environment-friendly fuels like BTL fuels exemplify an effective multi-partner collaborative R&D

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40. Statement of Dr. Tidu Maini, Executive Chairman of Qatar Science & Technology Park. See QSTP website at: http://www.qstp.org.qa/output/page2236.asp; Carl Atallah, Vice President of Chevron Qatar Energy Technology, in http://www.ameinfo.com/230640.html

41. "Qatar National Entities and Airbus Announce Major Environmental Initiative," Qatar Airways Press Release, January 10, 2010, available at: http://www1.qatarairways.com/global/en/newsroom/archive/press-release-10Jan10.html

42. "Qatar National Entities and Airbus Announce Major Environmental Initiative"; *MEED*, "Qatar Airways, Airbus to Develop Aviation Biofuels," January 10, 2010, available at: http://www.meed.com/sectors/transport/aviation-and-airports/qatar-airways-airbus-to-develop-aviation-biofuels/3027059.article; and Paul Nash, Ross Walker, Nicolas Mouney, *Alternative Fuels: A Flight Path towards Sustainable Aviation*, Airbus Publications, available at: http://www.airbus.com/fileadmin/media_gallery/files/brochures_publications/FAST_magazine/fast46-4-alternative-fuels.pdf

program that will establish them as an international hub for the application of new platform technologies.[43] It is worth mentioning that in a context where QSTP aims to become an incubator for start-up ventures, thus helping to commercialize the products of Qatar's investment in research and development, any scientific discovery is expected to be under Qatari license patents solely or shared with the companies that collaborated in the invention.[44]

Photovoltaic Manufacturing

Qatar's approach to the development of renewable energy sources (RES) is characterized by a firm focus on applied research activities or business feasibility planning of related technologies. The potential development on BTL biofuel production and commercialization or the Qatar Solar Technologies' (QSTec) manufacturing facility for PV cells and modules may be cited as examples. Indeed, in addition to promoting its financial sustainability, Qatar Foundation's first investment in Qatar Solar Technologies (QSTec) intends to support Qatar's strategic objectives to diversify its economy and benefit from an internationally growing photovoltaic market.

Launched in March 2010, QSTec, which is headquartered in Qatar, is a joint venture between Qatar Foundation (70 percent), SolarWorld AG (29 percent), and the Qatar Development Bank (1 percent). With an initial investment valued at over $500 million, the company is developing a polysilicon production plant on 1.2 million square meters of land in Ras Laffan Industrial City. In its first stage scheduled to be completed by 2012, the plant's production line will have a capacity of 4,000 metric tons of polycrystalline-silicon per year, designed to expand as demand grows. The facility is expected to provide employment for several hundred people in a wide range of fields and intends to cater for regional and international markets.[45]

43. Statement of Dr. Tidu Maini in "Qatar National Entities and Airbus Announce Major Environmental Initiative."

44. For general QSTP regulations, see QSTP website: www.qstp.org.qa

45. Qatar Foundation, Press Release, March 2010, available at: http://www.ameinfo.com/225489.html ; and *Qatar National Strategy 2011-2016*, 85. SolarWorld is responsible for all steps in the production process from raw silicon to PV modules and systems. The company was responsible for several breakthroughs in the PV sector, developing the first grid-connected PV systems and the first UL-listed PV modules. In particular, for QSTec manufacturing plant, the production line technology will be provided by the German company Centrotherm Photovoltaics AG; in Floyd Associates Inc., *Solar Power: Photovoltaic Technologies* (May 2010), available at http://

Early Stages of Renewable Energy Deployment

RE resources in Qatar present opportunities for the country to enhance its future energy mix. According to the Qatar National Strategy 2011-2016, RE technologies together with energy efficiency measures should help conserve gas and reduce carbon emissions.[46] However, despite such rationale and the promising physical potential of the solar and wind energy sources, Qatar is still in the early stages of deploying these technologies.

For instance, KAHRAMAA has recently started considering other alternatives to gas-fired power and desalination plants. In 2008, prompted by the ever-expanding schemes of the power and water sectors in Qatar and the region and the looming gas shortages from the North Field, the authority announced the construction of a 3.5 GW integrated solar combined-cycle plants by 2013. In theory, the projects will be using CSP technologies to generate electricity and desalinate sea water, wherein up to 500MW of solar thermal technology can be deployed in the same place. According to a KAHRAMAA official, the solar complex was part of a wider plan that could include the construction of a nuclear power plant in Qatar. It has been announced that the design of the plant would be completed by the end of 2009. However, the progress on such a major project has not been communicated yet.[47]

Another planned project announced in 2009 is the setting up of a large photovoltaic energy power plant of 100MW to be implemented in QSTP by 2014. The key components of the solar cells and modules to be used in this power plant are likely to come from a Qatar-based polycrystalline silicon production facility, under construction by Qatar Solar Technologies (QSTec). As the first phase of QSTec polysilicon facility is scheduled for completion in 2012, such photovoltaic

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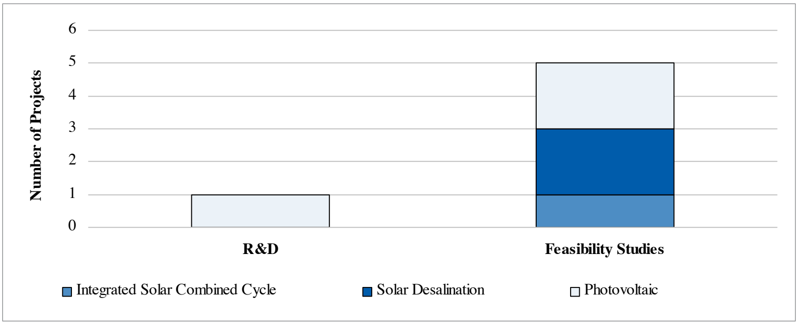
www.floyd-associates.com/solar3.pdf, 10; The contract with Centrotherm Photovoltaics AG was awarded immediately after the joint venture announcement. See Qatar Foundation Press Release, March 2010; Plant's characteristics in QF-QSTec webpage: http://www.qf.org.qa/joint-ventures/qatar-solar-technologies

46. *Qatar National Strategy 2011-2016*, 85.

47. Statement by Salah Hamza, senior business development planner at KAHRAMAA, to *MEED*; the nuclear plan would be based in Umm Bab and have a capacity of 1,080MW by 2018. See Elizabeth Bains, "Qatar Electricity & Water Company"; talks with international energy companies over this or a similar solar energy generation project were taking place in early 2010. See Peter Salisbury, "BP Plans Qatar Solar Plant Scheme," in *MEED*, January 2010, http://www.meed.com/sectors/power/renewable-energy/bp-plans-qatar-solar-plant-scheme/3003535.article; the same source announced yet another – 750 KW – PV deployment project in Qatar by BP Solar, but without further development.

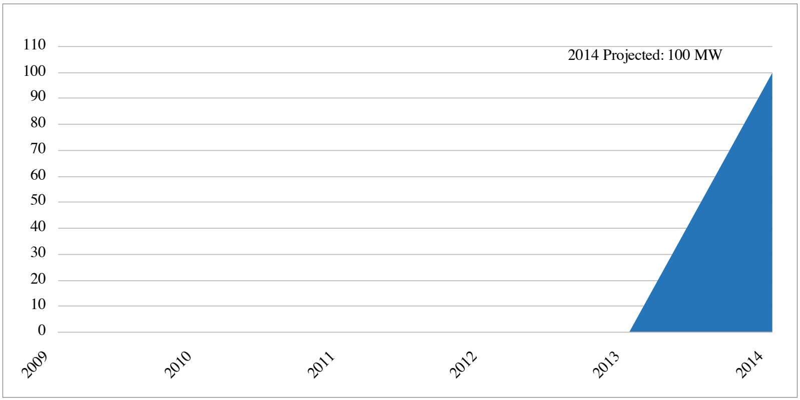
deployment would take place only sometime later.[48]

Number of Renewable Energy Projects in Qatar per Nature and Technology (up to 2014)



No RES project has been deployed in Qatar yet.
Source: Author's calculation.

RES Projects Qatar - Cumulative Capacity (MW)



When completed in 2014, the 100MW-capacity PV Energy Plant of the Polysilicon production facility will be Qatar's first project to generate energy from renewable sources.
Source: Author's calculation.

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48. Information on this projected PV deployment are from Matthew Scotland, "Top 10 Gulf Power Projects," *Arabian Oil and Gas*, May 21, 2009, available at: http://www.arabianoilandgas.com/article-5520-top-10-gulf-power-projects/1/print/ and "Qatar Foundation Enters Solar Energy Sector with Launch of Qatar Solar Technologies," Press Release Qatar, March 2, 2010 available at: http://www.ameinfo.com/225489.html and QSTec webpage: http://www.qf.org.qa/joint-ventures/qatar-solar-technologies

It is worth mentioning that the World Cup event due to take place in Qatar in 2022 could present opportunities for additional RE deployment in the country. Not only would this diversify the energy mix of the country – according to some estimates, the installed power capacity could reach 13.5 GW by 2019[49] – but it would also expand the market for solar products, in particular QSTec PV cells and panel.

Indeed, as the organizing committee aims to host a carbon neutral event, it was announced that five of the planned stadiums would use solar power. Such investment potential prompted international architectural firm Arup to implement a 500-seat model stadium to test the feasibility of large-scale solar cooling technology. Named the Qatar 2022 Showcase, the model stadium used photovoltaic and CSP technologies to produce its air-conditioning and its first testing was reported to have been satisfactory.[50]

In reality, if developers in Qatar successfully integrate solar technologies into such large spaces, then – because of the enormous potential of energy saving this represents – the entire construction sector could be incentivized to adopt them.

Prospects for Building-Integrated Photovoltaics (BIPV)

Qatar's socio-economic growth has been so fast for the last decade that it is important that such development trend should be continued sustainably. Environmental protection and, more specifically, awareness among the construction sector stakeholders about green building environmental benefits now appears to be gaining momentum in Qatar.

With this in mind, Qatar Green Building Council (QGBC), supported by Qatar Foundation and affiliated to the World Green Building Council (WGBC) as a "Prospective Council" since 2009, will develop a definitive set of green building standards to be used by developers in the construction and property industry. In the meantime, though, the council is expected to support certification programs for sustainable building practices like Leadership in Energy and Environmental Design (LEED) of the US or BREEAM of the UK.[51]

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49. MEED, "Doha Power Sector Enters the Comfort Zone," http://www.meed.com/supplements/2010/middle-east-power-survey/dohas-power-sector-enters-the-comfort-zone/3073360.article

50. During the FIFA visit in September 2010, with the outside temperature having reached 44 degrees Celsius, the temperature on the pitch was recorded as 23 degrees Celsius. See Sarah Cowell, "Solar Power to Cool Stadiums in Qatar," *MEED* supplements, 2011, http://www.meed.com/supplements/2011/qatar-projects/solar-power-to-cool-stadiums-in-qatar/3086060.article

51. QGBC website: http://www.qatargbc.org/index.php ; "Qatar Green Building Council Membership

However, LEED and BREEAM have their critics in the region; they argue that these assessment systems are inadequate for green buildings in the GCC countries. This may explain why they have not struck a chord with Qatari authorities.[52] More locally, QGBC teamed up with Barwa Qatari Diar Research Institute (BQDRI) to work on green building guidelines.

BQDRI had already developed Qatar Sustainability Assessment System (QSAS) and in 2010, it signed an agreement with Qatar's Public Works Authority (Ashghal) to develop all of its future projects to QSAS standards, including ratings on water and energy efficiency, materials selection, and improved design. This represented the first government endorsement of the QSAS. In summary, the ratings system focuses on specific local needs and environment constraints in Qatar and is mainly a combination of different categories found in LEED, BREEAM, and Estedama of Abu Dhabi.[53] More recently, it was announced that BQDRI/QSAS will establish green building standards to which all government buildings will have to conform by 2016. All new commercial buildings and residential buildings will be brought into the new regime at a later stage.[54]

In parallel, the construction of the new Qatar National Convention Centre (QNCC) has been conducted according to the gold certification standard of the Leadership in Energy and Environment Design (LEED), the US Green Building Council rating system. In addition to energy and water conservation technologies, 3,500 square meters of solar panels were integrated with the building's design, which will provide 12.5 per cent of the building's total electrical requirements, when fully operational.[55]

Such green technologies are welcome; however, as experts rightly point out,

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Drive Generates Wide Response," Ameinfo at: http://www.ameinfo.com/246305.html; The Council has joined the Dubai-based Emirates Green Building Council (EGBC) and Jordan Green Building Council to set up the Middle Eastern Green Building Councils Network (ME GBC Network). See *The Peninsula*, "Plan to Form Mideast Green Building Network," September 28, 2010 at http://www.thepeninsulaqatar.com/qatar/127414-plan-to-form-mideast-green-building-network.html

52. J. Roberts, "Gulf States Are Building Green for the Local Environment," *MEED*, July 2010, http://www.meed.com/sectors/construction/gulf-states-are-building-green-for-the-local-environment/3007872.article

53. Ibid.

54. Announcement made in *Qatar National Development Strategy Report 2011-2016*, 222.

55. The QNCC is a member of the Qatar Foundation and hosted the World Petroleum Congress in December 2011; QNCC website: http://www.qf.org.qa/joint-ventures/qatar-national-convention-center/qatar-national-convention-center?t=316

the country will not be ready to fully embrace the green building movement unless the government passes legislation and makes the system mandatory. [56]

Sustainability, Policies, and Incentives

Holding the world's third largest natural gas reserves and being a significant net exporter of oil,[57] Qatar paid no attention to the potential of renewable energy until recently when it took some steps to endorse the development of RES on local and international levels.

In 2009, Qatar signed up to join the International Renewable Energy Agency (IRENA).[58] Locally, Qatar's Ministry of Energy and Industry announced that it intends to create a committee to examine the potential of renewable energy resources in Qatar.[59]

On the environmental front, Qatar adopted the principles of Agenda 21 of the United Nations Conference on Environment and Development (UNCED) which calls, among other things, for the commitment of the state to institutionalize environmental impact assessment for its new development projects. Within this context, a policy has been laid down for environmental impact assessment of major infrastructure projects.[60] Nevertheless, up to 2005, Qatar's status report on its National Sustainable Development Strategy (NSDS) indicated that "there is no NSDS as such, but there are many national institutions that are involved in sustainable development. Their efforts need however to be coordinated to achieve more efficiency and to optimize resources."[61]

According to experts, Qatar could invest in the renewable energy sector to

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56. Statement by Issa M. Al Mohannadi, CEO of Dohaland and Founder and Chairman of the Qatar Green Building Council, in "Qatar Green Building Council to Develop Sustainable Property Industry for Qatar," *The Peninsula,* July 7, 2009.

57. US Energy Information Agency, *Qatar Analysis Brief* accessible at: http://205.254.135.24/countries/cab.cfm?fips=QA

58. Verity Ratcliffe, "Qatar Signs up to International Renewable Energy Statute," *MEED,* June 2010, http://www.meed.com/sectors/power/renewable-energy/qatar-signs-up-to-international-renewable-energy-statute/3007423.article

59. *Qatar National Development Strategy 2011-2016,* 85.

60. Doukas, Patlizianas, Kagiannas, and Psarras, "Renewable Energy Sources and Rational Use of Energy Development in the Countries of GCC: Myth or Reality," *Renewable Energy* 31 (2006).

61. UN Department of Economic and Social Affairs, Division of Sustainable Development, available at: http://www.un.org/esa/dsd/dsd_aofw_ni/ni_natiinfo_qatar.shtml

promote a national low-carbon economy. In particular, it was recommended that Qatar's sovereign wealth fund Qatar Investment Authority (QIA) engage with policy-makers to discuss ways of enhancing sound investments in this sector and related Clean Development Mechanisms.[62] More generally, it was stated that in order to ensure sustainable social development, national policies are needed to balance intensive energy-based economic growth. Such policies should be reflected in all socio-economic planning and programs so as to reduce the potential human, economic and environmental impact that would result in shortages, inherited ecological damage, or extended societal disruption.[63]

In particular, low prices of fossil fuel power generation and the fact that RES technologies are not tested yet locally are definitely adding to the difficulty of changing Qatar's over-reliance on hydrocarbons. For this to happen, a pioneering attitude and political efforts are needed to support RE technology utilization in the country. Under the responsibility of KAHRAMAA, electricity and water tariffs have been heavily subsidized for decades. This makes RE technologies comparatively more expensive to deploy, and hence less attractive for investments than are gas-fired electricity and water generation projects.

Sustainability imperatives and economic efficiency should, however, push the government, which purchases fossil-fuel generated electricity and water from the IPWPs through KAHRAAMA, to find ways to minimize the cost of gas consumed in producing these commodities and make tariffs reflect these costs, on the one hand, and seek to develop clean sources of energy, on the other hand. This, in turn, would enhance end-use energy efficiency and help mitigate the country's environmental risks. Indeed, strategic imperatives related to RE development in Qatar could be about protection of the environment. Within such a small territory, the carbon emissions caused by a booming economy and population growth threaten the health of the inhabitants. A shift from the culture of waste is of utmost importance, and adoption of solar technologies especially integrated into the built environment will further reinforce such movement.

Qatar has not set targets for RES contribution to its future energy mix nor has it established a general regulatory framework for RES investments. In fact, so far, with the exception of technological R&D or industrial projects, deployment of

62. Alastair Newton, managing director of Nomura International, quoted in Santhosh V. Perumal, "QIA Urged to Focus on Renewable Energy Spend," *Gulf Times*, October 6, 2009, available at: http://www.gulf-times.com/site/topics/article.asp?cu_no=2&item_no=318672&version=1&template_id=48&parent_id=28

63. *Qatar National Development Strategy 2011-2016,* 194.

solar or wind energy sources has been limited, almost non-existent, in Qatar. The introduction of national RE targets, tax credits, or other incentives (like the feed-in-tariffs) should certainly heighten the importance and dynamism of its national RE market. As has been witnessed in its power generation sector since the 1990s, Public-Private Partnerships (PPP) have become the model for procuring new power and water desalination capacity in Qatar.[64] Such long-established experience in PPP in the country can offer a model framework within which RES deployment projects can thrive. These can be structured as build-own-operate-transfer (BOOT) schemes.

64. For this purpose, Business & Trade Ministry has a PPP directorate, the Qatar Chamber of Commerce & Industry has called for a comprehensive PPP framework and legislation needs to be put in place. See Ed James, “Embracing Public-Private Schemes in Qatar.”

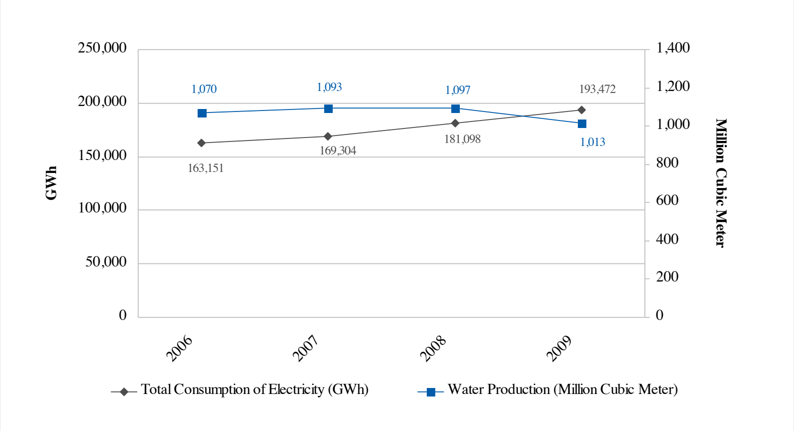
Chapter Five

Saudi Arabia

Electricity: Urbanization and Growing Demand

The Kingdom of Saudi Arabia, a major producer of oil, is also a big consumer of energy where increasing population, industrial diversification and overall improvement in the standard of living are leading to a growth in demand for electricity, thus putting pressure on its natural resources.

Growth in Electricity and Water Consumption - Saudi Arabia

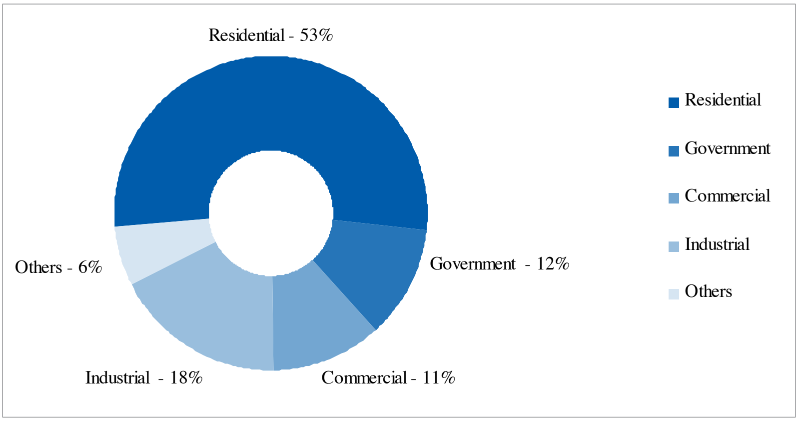


In the past years, Saudi Arabia's consumption of electricity has grown by an average of 6 percent per annum. Water production has remained stable.
Source: Saudi Arabia's Electricity and Cogeneration Regulatory Authority (ECRA) Annual Reports, 2006-2009

In 2005, the Saudi population reached 23.12 million and per capita electricity consumption recorded 6,813 KWh/cap; per capita electricity consumption grew by 3.7 percent annually between 2005 and 2008, while population increased by 2.2 percent annually for the same period.[1]

According to the Ministry of Water and Electricity, the residential sector consumed around 53 percent of the total electricity sold in 2007, while the industrial sector used 18 percent, the government 11.7 percent, and the commercial sector 11.4 percent. Close examination shows that from 2004 to 2007, the commercial sector accounted for the most rapidly growing segment of electricity demand (12 percent annually), followed by households (around 7.5 percent annually) and the governmental sector (6 percent annually); meanwhile, the industrial sector's electricity consumption shrunk by an average of 2.4 percent annually for the same period, decreasing from 33,059 GWh/year in 2004 to 30,635 GWH/year in 2007. It is clear that, besides accounting for at least 76 percent of the total consumed electricity in the country in 2007, the built environment in Saudi Arabia is responsible for the ever-increasing demand.[2]

Electricity Consumption by Sector (%) - 2007



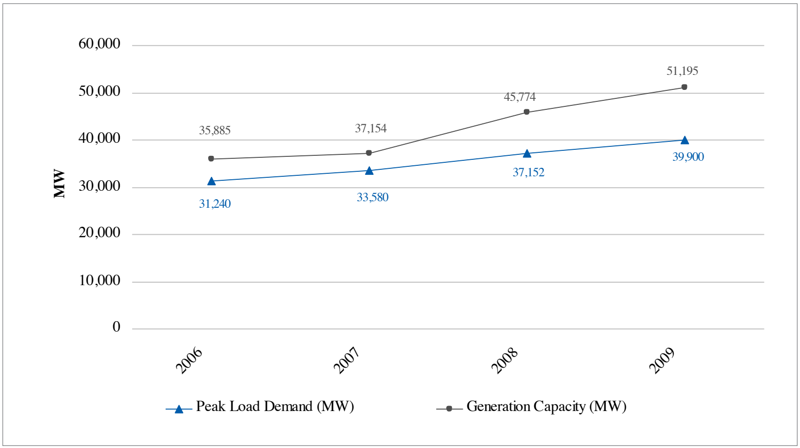
The residential sector accounts for more than half of the total consumption of electricity in Saudi Arabia. Others include Agriculture, Mosques, and Hospitals.
Source: Based on Ministry of Water and Electricity statistics (2007)

1. Calculations are based on statistics from International Energy Agency, *Key World Energy Statistics*, 2007 and 2010.
2. Calculations are based on government's statistics; see Ministry of Water and Electricity, *Electricity, Growth and Development in the Kingdom of Saudi Arabia* (2007), 41.

As in most GCC countries, air-conditioning accounts for almost 80 percent of Saudi households' electricity consumption because of the harsh climate conditions and buildings which are far from being energy-efficient. Increased urbanization can thus exacerbate the situation, unless more climate-responsive architecture is introduced as well as renewable energy (RE) technologies are used. In this context, it was estimated that energy conservation measures can reduce a building's annual electricity consumption by 32.4 percent, and incorporation of photovoltaic panels on the roof of the building, can save an extra 10 percent of the total consumption.[3]

In general, total consumption of electricity grew by 6.2 percent annually between 2006 and 2009, when it registered a total of 193,472 GWh/year. At the same year, electricity peak demand hit 39.9GW, a 7.5 percent increase from 2008.

Saudi Arabia Electricity Capacity and Peak Load 2006 - 2009



Saudi Arabia's electricity capacity and peak load have increased in parallel in the past years, which allowed to maintain a reserve margin between 10 and 20 percent. However, decommissioning of 5 GW is expected by 2015, while peak load is expected to continue rising.
Source: Based on Electricity and Cogeneration Regulatory Authority (ECRA) Annual Reports, 2006-2009

In parallel, the Kingdom's power generation capacity grew by 11.8 percent,

3. For more information on electricity use, water consumption and potential energy conservation in a typical Saudi residential building, see H.M. Taleb and S. Sharples, "Developing Sustainable Residential Buildings in Saudi Arabia: A Case Study," *Applied Energy* 88 (2011): 383-391.

reaching 51.2 GW in 2009, and achieving a reserve margin of 22 percent. Nevertheless, due to the expected growth in population and gross domestic product (GDP) in Saudi Arabia, peak demand will rise; initially estimated to reach 53.3 GW by 2020, the figure was revised by the Ministry of Water and Electricity (MWE) to 77.4 GW.[4] Hence, Saudi Arabia would need to invest more than the SR300 billion ($80 billion) announced by the Electricity and Cogeneration Regulatory Authority (ECRA) in 2010 to boost installed capacity by 2020, [5] especially that the country's electricity system will face the decommissioning of 5 GW of its generating capacity by 2015.[6] Besides satisfying rising consumption levels, new power stations are also needed to maintain the reserve margin (10-20 per cent of total capacity).

The challenges posed by such rising demand require both public and private investments to participate in funding the Kingdom's power plans. For this, the electricity sector is being restructured, and regulations and incentives are being implemented. As part of the reform process, ECRA – established in 2001 to regulate the supply of electricity – is in charge of issuing licenses for electricity projects and ensuring compliance with conditions of licenses. In this context, major industrial consumers were allowed to generate their own power and sell excess to the main authority responsible for power generation in the country, the Saudi Electricity Company (SEC).[7]

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4. This was based on an average annual growth rate of 8.5 percent for the period 2010-2020. Source: MWE.
5. According to ECRA, installed capacity was forecasted to reach 67 GW by 2020, and to 120 GW by 2030; Abdulla Al-Shehri, governor for regulatory affairs at the Electricity and Cooperation Regulatory Authority (ECRA), quoted in Reuters, "Saudi Power Demand to Triple by 2032," May 18, 2010; and Ahmad Al-Khowaiter, director of new business evaluation department at ARAMCO, quoted in Reuters, "Kingdom Sees Surge in Solar Energy Output," May 21, 2010. "Saudi Power Sector Set for Huge Expansion," June 19, 2008 in http://www.ameinfo.com/160931.html;
6. Bernadette Redfern, "Riyadh Commits to New Power Capacity," *Arabian Power and Water Market Report 2011*, *MEED* (2011) and Digby Lidstone, "Saudi Arabia Straining to Meet Demand," *MEED GCC Power 2010 Supplement*, *MEED* (2010).
7. Hassan K. Al-Asaad, "GCC: The Backbone of Power Sector Reform," available online at http://www.gccia.com.sa/articles/GCC-%20The%20Backbone%20of%20Power%20Sector%20Reform.pdf In 2010, SEC had some 40.5 GW as installed capacity; other public (SWCC) and private power producers (e.g., ARAMCO) provided for the remaining. According to SEC's 2009 annual report, it is expected that the utility's capacity will reach 50 GW by 2015 and 70 GW by 2020. See "Saudi SEC Power Capacity to Rise by 12,043 MW," March 4, 2010, http://www.utilities-me.com/article-401-saudi-sec-power-capacity-to-rise-by-12043mw/; and SEC's 2009 annual report.

Water Scarcity

The rapid socio-economic growth caused per capita water demand to increase significantly, and together with the water stress experienced by the Kingdom,[8] this made Saudi Arabia the first country worldwide to use water desalination to meet potable water needs for urban, rural and industrial applications.[9]

In 2006, 1070 million cubic meters (million m^3) of desalinated water were produced on both the west and east coasts of the country; this figure increased by 1.2 percent annually to reach 1096.7 million m^3 in 2008, before falling to 1013.1 million m^3 in 2009. The decrease is mainly due to scheduled maintenance and to sector restructuring in order to accommodate entry of new projects. Indeed, Saudi Arabia's main provider of desalinated water, Saline Water Conversion Corporation (SWCC), is owned by the state and will be transformed into a holding company with subsidiaries formed as production companies. The private sector would eventually participate in ownership of the holding companies as well as the subsidiaries, as is the case with independent cogeneration companies (or Independent Water and Power Projects).[10] Behind such a strategy are the Kingdom's forecasts for an increasing demand for desalinated water; according to SWCC, a capacity of 1,290 million gallons a day must be added by 2024. This would eventually allow an extra annual production of 2,139 million m^3 of water to meet demand. Other forecasts also predict that, up to 2020, the country will need to spend at least $50 billion on water desalination projects, many of which would be integrated with power generation capacity.[11]

In fact, most plants owned by SWCC are of the cogeneration type, where desalted water is produced simultaneously with electricity to reduce fuel consumption.[12] For instance, SWCC has recently started the construction of what

8. M.A. Dawoud, "The Role of Desalination in Augmentation of Water Supply in GCC Countries," *Desalination* 186 (2005): 187-198. The author claims that water stress in Saudi Arabia is partly due to the adopted policy of food self-sufficiency which imposed continual constraints on the allocation of water resources and which would otherwise reduce the share for agriculture in favor of increased domestic and industrial demand.

9. In 2009, the Kingdom's production of desalinated water represents 18.1 percent of world production and makes the Kingdom the largest producer in the world. See ECRA, *Annual Report 2009*, 33.

10. ECRA, *Annual Report 2009*.

11. Redfern, "Riyadh Commits to New Power Capacity."

12. SWCC sells most of its electricity production to Saudi Electricity Company (SEC). Its electricity production capacity represented 10 percent of total Saudi capacity in 2009; for the same year,

should be the largest Multiple Effect Distillation (MED) desalination plant in Yanbu. The advantages of the MED technology are mainly its very low electrical consumption (less than 1.0 KWh/m^3), and the fact that it is ideal for coupling with power plants.[13]

Sustainable supply of power and water are closely related growth challenges in Saudi Arabia, hence producing these commodities with less hydrocarbon inputs and by means of renewable sources of energy should be considered as strategic economic development for both sectors. Furthermore, steam-powered processes for electricity production can easily incorporate solar thermal technologies, namely Concentrating Solar Power (CSP), to generate important volumes of steam. So the energy diversification paradigm can easily justify investment in solar technologies for SWCC's water and electricity facilities and operations.[14]

Gas Shortages and the Energy Efficiency Imperative

Notwithstanding the need for private investments and Independent Water and/or Power production (IWPP) to satisfy domestic demand, the energy security outlook calls for implementation of energy efficiency measures as well as the development of renewable energy initiatives in Saudi Arabia.

Electricity an water production in KSA are completely dependent on burning of fossil fuels. In 2009, the Kingdom consumed approximately 2.4 million barrels a day of oil (bbl/d) in total, up 50 percent from the year 2000. Contributing to this growth is the rise in burning of crude oil for power and water generation, which reaches 1.2 million barrel per day (bbl/d) during the summer months.[15]

According to the Ministry of Water and Electricity, the energy consumed in

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SEC accounted for some 80 percent, and other producers for the remaining 10 percent. See ECRA *Annual Report*, 19 and 34.

13. For this project, SWCC is partnering with Doosan Heavy Industries and Construction. See *Saudi Gazette*, "Largest MED Desalination Plant to be Built in Yanbu," February 9, 2011; more on Multiple Effect Distillation can be found at: http://www.entropie.com/en/services/desalination/MED/

14. At the time of writing, we learned that SWCC has signed an agreement with Hitachi Zosen Corporation of Japan to conduct research on solar desalination. See P.K. Abdul Ghafour, "Saudi Arabia to Exploit Solar Energy for Desalination Plants," *Arab News*, December 2, 2011, available at: http://arabnews.com/saudiarabia/article541758.ece

15. Energy Information Administration, *Country Analysis Brief - Saudi Arabia,* January 2011 available at: http://www.eia.doe.gov/cabs/Saudi_Arabia/Full.html ;

electricity generation reached 45.76 million of Tons of Oil Equivalent (TOE) in 2007, 16.74 percent higher than in 2004.[16] Of the total amount of fuel burned to generate electricity in 2007, 20.5 million of TOE came from natural gas (22.78 billion cubic meters NG), and the rest from diesel (9,287,591 tons), crude oil (7,566,051 tons) and heavy fuel oil (6,233,075 tons). From 2004 to 2007, statistics show that the share of gas and diesel is diminishing whereas that of oil and fuel oil has been increasing over the years.[17] Indeed, feedstock for the generation capacity increase was initially expected to be natural gas. However, many new facilities are crude oil-fired due to constraints on domestic natural gas supplies.[18]

Many stakeholders believe that if these trends continue unchanged, the growing demand for oil-fed power generation systems will eventually adversely impact the nation's oil exports, which now account for a large part of the Kingdom's GDP. ARAMCO estimates that the total domestic demand is expected to rise from about 3.4m b/d of oil equivalent in 2009 to approximately 8.3m b/d in 2028, an increase of almost 250 per cent that would cause Saudi Arabia's stockpile of crude oil for export to fall by as much as 3 million barrels per day by that date.[19]

In the context of continuous socio-economic growth, such prospects worry oil officials in Saudi Arabia. They have been calling for rationalizing the use of energy, insisting that, while maintaining the same economic growth, demand could be halved by energy efficiency improvement measures and by tackling subsidies that cost the country billions of dollars each year and foster a culture of waste. [20]

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16. This amount represented 30.4 percent of Saudi Arabia's Total Primary Energy Supply (TPES) in 2007 (150.33 million TOE). In 2006, the energy consumed in electricity generation amounted to 30.2 percent of KSA TPES for the same year, i.e., 146.11 million TOE (based on IEA, *Key World Energy Statistics* for 2010 and 2008, respectively.

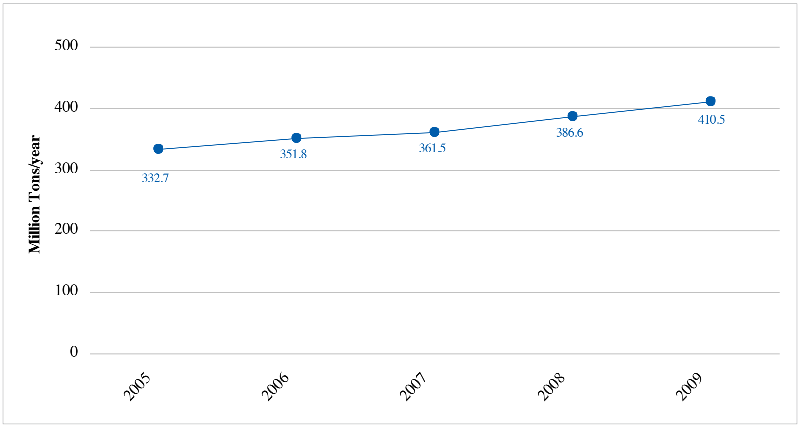
17. Ministry of Water and Electricity, *Electricity, Growth and Development in the Kingdom of Saudi Arabia*, 37

18. A royal decree, issued in the spring of 2006, requires that all future coastal power plants utilize crude feedstock at a set price of $0.46 per million BTU. See Energy Information Administration at http://www.eia.doe.gov/cabs/Saudi_Arabia/Electricity.html

19. Khaled Al Falih, CEO of ARAMCO, in a speech at the MIT Club of Saudi Arabia, Riyadh, April 19, 2010, and in *Financial Times*, "Awkward Questions about Oil," May 3, 2010; and Mohammed Ali Trabulsi, ARAMCO's executive director of pipelines, distribution and terminals, Lecture on Renewable Energy organized by the Center of Research Excellence in Renewable Energy at King Fahd University of Petroleum and Minerals, April 26 2010; see "Experts Suggest Saudi Arabia Develop Renewable Energy," article available at http://www.menafn.com/qn_news_story_s.asp?StoryId=1093325998&src=MOEN)

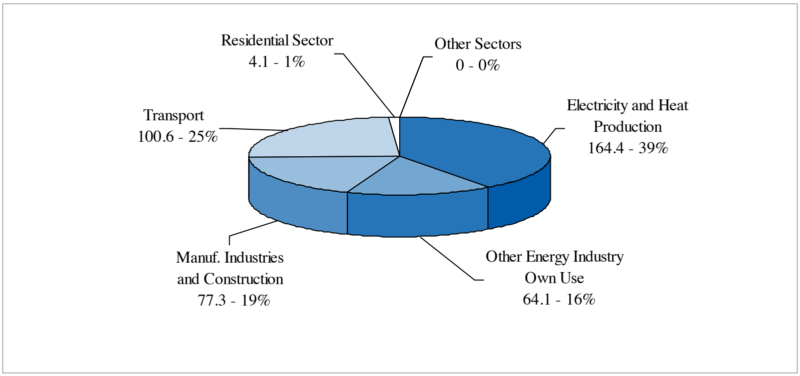
20. Statement by Al Falih, see note 19.

Saudi Arabia CO_2 Emissions 2005 - 2009



Source: Based on IEA, *CO_2 Highlights* (2011)

Saudi Arabia CO_2 Emissions from Fuel Combustion in 2009 by Sector (million tons)



Between 2005 and 2009, Saudi Arabia's CO_2 emissions have increased by an average of 5.8 percent per year, well ahead of its population growth (2.2 percent). Electricity and heat production accounts for 40 percent of all CO_2 emissions from fuel combustion.
Source: Based on IEA, *CO_2 Highlights* (2011)

At a subsidized price of the British Thermal Unit (Btu) for the power generation sector, the production of one unit of electricity in the Kingdom costs SR0.138 per KWh (which is equivalent to \$0.0368/KWh).[21] Yet, according to ECRA reports,

21. According to EIA, a barrel of oil at \$70/barrel produces 1,700 KWh at a cost approximately

the unit of electricity in the Kingdom is sold at as low a price as SR0.05 ($0.0133) to the residential sector and SR0.12 ($0.032) to the industrial sector. Obviously such artificially low prices of electricity – due to huge cross-subsidies in the power sector – are costing the country dearly.[22] They also encourage wasteful consumption and weaken environmental awareness in the country.

In addition to ramping up growth in electricity demand, energy intensity was progressing at an average rate of +1.6 percent annually between 2005 and 2008, while it was decreasing by an average annual rate of -2.9 percent in South Africa, -3.2 percent in India, and - 3.6 percent in China for the same period.[23] Hence, energy efficiency measures are poised to play a major role in conserving the hydrocarbons in Saudi Arabia.[24] However, in the mid to long term they are not enough.

In addition to energy efficiency imperative, the challenge for Saudi energy stakeholders is to add new power generating capacity while using the hydrocarbons reserves to the Kingdom's best advantage. Hence, fuel savings should also drive interest in the utilization of alternative sources to help prolong these reserves and preserve the non-renewable oil and gas export capacity. In addition to enabling diversion of bigger proportions of fossil fuels to refineries and high-value petrochemical industries, renewable energy use will also cut the carbon emissions, the hydrocarbons are responsible for.

Potential of Renewable Energy Sources (RES)

With a total area of 2.15 million km^2, Saudi Arabia is the largest of the GCC countries. According to FAO, the Kingdom has four main physiographic regions:

- The western mountains with the highest peak at 2,000m above the sea;

$0.05/KWh; with the price of crude above $100 a barrel on the international market, the cost of electricity produced from oil is even higher. In 2009, the average cost of a unit of electricity (kWh) in KSA was about SR0.138; see ECRA, "Activities and Achievements of the Authority in 2009," *Annual Report* 2009, 32.

22. In May 2011, it was reported that 800,000 barrels of oil equivalent (Boe) per day were consumed in Saudi Arabia's power plants: Ziyad Al Shiha, the executive director of Saudi ARAMCO Power Systems, quoted in Florian Neuroff, "Saudis Kicking off Major Move into Solar," *The National*, December 23, 2011.

23. Based on energy intensity values by the International Energy Agency; see IEA, *Key World Energy Statistics*, 2007-2010 reports.

24. More on energy conservation prospects in Saudi Arabia in S.A. Al-Ajlan, A.M. Al-Ibrahim, M. Abdulkhaleq and F.Alghamdi, "Developing Sustainable Energy Policies for Electrical Energy Conservation in Saudi Arabia," *Energy Policy* 34 (2006): 1556-1565.

- The central hills stretching from the mountains to the center of the country, where the summer (May to October) is overwhelmingly hot and dry while winter is dry and cool, with night temperatures close to freezing

- The desert regions with its sand dunes lie to the east of the central hills towards the south and south east of the country

- The coastal region including the western strip along the Red Sea and the plains of the eastern coast with its oases. These regions are hot and humid in the summer and warm in winter.

The country has 2,230 km of coastline, but the greater part of its total area is arid with relatively cloudless skies for the most part of the year and great extremes of temperature between the seasons. Prevailing winds reaching Saudi Arabia are dry winds from the north, producing sand and dust when they blow and accentuating the aridity of the Kingdom's climate.[25]

Whereas Saudi Arabia engaged in extensive cooperation in RE research and development projects as early as the mid 1970s,[26] precise measurements of the country's solar and wind natural resources was not conducted before the mid 1990s. In 1993, the US-based National Renewable Energy Laboratory and the King Abdulaziz City for Science and Technology (KACST) initiated what was called a "New Energy Project" consisting of two separate assessment programs to record reliable data and compile solar and wind atlases covering different parts of Saudi Arabia. Existing information at that time, collected by "old and un-calibrated instruments," was considered not to be sufficient to assess the real RE potential in the Kingdom.[27]

Accordingly, from 1993 to 2000, KACST and NREL conducted a joint project to upgrade the solar resource assessment capability of Saudi Arabia. The US-Saudi Arabian Project on Solar Radiation Resource Assessment identified 12 stations representing the various climate and topographical regimes of the Kingdom where total solar radiation (Global Horizontal Irradiance GHI), direct beam radiation (Direct Normal Irradiance - DNI) and diffuse radiation were measured and centrally

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25. The higher parts of western and southwestern plain areas, while covering only 12 percent of the total area, accumulate almost 100 percent of the Saudi Arabia annual precipitations, which were estimated at 245.5 Km^3/year; see Karen Frenken (ed.), *Irrigation in the Middle East Region in Figures*, AQUASTAT Survey – 2008, FAO Land and Water Division (2008), KSA Chapter; 325-337; esp. 325-328.

26. A summary of these programs is presented in the section on Research and Development.

27. Saleh H. Alawaji, "Evaluation of Solar Energy Research and its Applications in Saudi Arabia - 20 Years of Experience," *Renewable and Sustainable Energy Reviews* 5 (2001).

collected at the solar village site of KACST. Similarly, a project for wind energy assessment was initiated by the Energy Research Institute (ERI) in 1995, where five locations – Abha, Arar Dhahran, Solar Village and Yanbu – were selected for wind speed monitoring and data collection. It is worth mentioning, however, that wind speed data collected and processed for these sites between 1995 and 2002 did not show significant differences from the old wind data previously collected in the 1986 Saudi Arabian Wind Atlas (1970-1982).[28]

Apart from the KACST-NREL solar radiation assessment project, numerous subsequent studies investigated the solar potential through older data collected in meteorological stations where GHI and sunshine duration have been recorded for the period 1970-1993 and were compiled in the Saudi Solar Radiation Atlas. Overall, results show that Saudi Arabia has vast areas subject to strong GHI suitable for Photovoltaic (PV) and high fractions of DNI, which is ideal for solar thermal or Concentrating Solar Power (CSP) technologies too.

Photovoltaic Energy

Assessing the solar energy potential for five main regions in Saudi Arabia, a study by King Fahd University found that average daily GHI amounted to 5,839 Wh/m^2 in Dhahran (Eastern region); 5,429 Wh/m^2 in Taif (Western region); 5,562 Wh/m^2 in Qurayat (Northern region); 5,824 Wh/m^2 Abha (Southern region); and 5,132 Wh/m^2 in Riyadh (central region).[29] These figures are consistent with the DLR study

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28. The 12 locations are: Riyadh, Gassim, Al-Ahsa, Al-Jouf, Tabuk, Madinah, Jeddah, Qaisumah, Wadi Al Dawasir, Sharurah, Abha, and Gizan. According to S.H. Alawaji, the solar radiation assessment projects have helped Saudi institutions gain valuable experience in the fields of instrumentation, calibration, data collection, and monitoring and analysis. See Alawaji, "Evaluation of Solar Energy Research and its Applications in Saudi Arabia"; The solar network data was made available on NREL internet site: http://rredc.nrel.gov/solar/new_data/Saudi_Arabia/ ; for KACST-NREL solar data analysis, see N.M. Al-Abbadi , S.H. Alawaji, M.Y.B Mahfoodh, D.R. Myers, S. Wilcox and M. Anderberg, "Saudi Arabian Solar Radiation Network Operation Data Collection and Quality Assessment," *Renewable Energy* 25 (2002): 219-234; for ERI wind data analysis, see S.H. Alawaji, N.N. Eugenio and U.A. Elani, *Wind Energy Resources Assessment in Saudi Arabia, Part II: Data Collection and Analysis*, Energy Research Institute (ERI), KACST; and N. M. Al-Abbadi, "Wind Energy Resources Assessment for Five Locations in Saudi Arabia," *Renewable Energy* 30 (2005): 1489-1499. The first Saudi Arabian Wind Energy Atlas was produced in 1986 by a research team from KACST and King Fahd University of Petroleum and Minerals (KFUPM) under SOLERAS.
29. S.M.Shaahid and M.A. Elhadidy, "Technical and Economic Assessment of Grid-Independent Hybrid Photovoltaic-Diesel-Battery Power Systems for Commercial Loads in Desert Environment,"

findings, which estimated the country's average annual GHI value at 2,130 KWh/m^2/year – a performance indicator that should yield an economic photovoltaic energy potential of 13.9 TWh/year in the Kingdom.[30]

Similarly, GHI and sunshine duration data from a network of 41 meteorological stations were compiled to analyze the distribution of solar radiation over Saudi Arabia. The study details the related values for each location, but overall it found that the mean GHI was 2.06 MWh/m^2/year and the duration of sunshine per day was 8h54' or 3,245 hours in a year. The ranking of the different locations was also performed in terms of potential annual energy production from a 5MW power plant installed in these locations and related costs of electricity (COE); results indicate that the best site for the development of PV electricity is Bisha and the worst is Tabuk and that the average photovoltaic annual energy production was 10.0GWh with an approximate efficiency of 23 percent, whereas the average COE is around $0.25/KWh.[31]

On the other hand, investigating the viability of hybrid PV-Diesel system to meet the power demand of a commercial building in Dhahran, a study by King Fahd University concluded that the Cost of Electricity (COE) for such a system amounts to $0.149/KWh – at a diesel fuel price of $0.1/liter – compared with $0.087 /KWh for diesel only system. The annual consumption of the selected building is 620,000KWh/year with a peak demand of 159 KW; accordingly, the optimum simulated hybrid system was found – using NREL-HOMER software – to consist of 80KW PV panels, 175 KW diesel generators and battery storage of three hours. Results indicated that in this optimal case the PV electricity contribution in the total system load reaches 26 percent; the total fuel consumption is 27 percent less than in the diesel-only system, and as a consequence, 44 tons of CO_2 emissions are avoided.[32]

Renewable and Sustainable Energy Reviews 11 (2007): 1794-1810.

30. GHI is estimated for surfaces tilted south with the country's latitude angle; the economic potential for PV technology is based on general PV growth rate. See German Aerospace Center (DLR), *Concentrating Solar Power for the Mediterranean Region,* 2005, 57.

31. The study uses RetScreen Software; it assumes a grid connected 5MW plant for all sites considered combined with inverters of total rated capacity of 4,750 KW and 95 percent efficiency to convert DC to AC to directly feed the grid. See S. Rehman, M.A. Bader and S.A. Al-Moallem, "Cost of Solar Energy Generated Using PV Panels," *Renewable and Sustainable Energy Reviews* 11 (2007): 1843-1857.

32. Shaahid and Elhadidy, "Technical and Economic Assessment of Grid-Independent Hybrid Photovoltaic-Diesel-Battery Power Systems."

In a similar techno-economic feasibility study, a hybrid PV-diesel-battery power system was simulated to meet the annual electrical demand amounting to 15,943 MWh of remote Rawdhat-Bin-Habbas village. The proposed 2.5 MW PV system, coupled with 4.5 MW diesel generators and battery storage of 1 hour, showed that the PV electricity penetration (optimum fraction of total electricity generated by the system) is 27 percent, and that the COE is $0.17/KWh – at a diesel fuel price of $0.1/liter – compared to 0.048 /KWh in case of diesel-only system.[33]

In both hybrid schemes it was found that the PV panels accounted for the bulk (80 to 84 percent, respectively) of the total initial capital cost of the PV-diesel system. Similarly, for the 5MW PV system discussed earlier, the major chunk (70 percent) of the plant's total initial cost was found to be due to the PV panels.

This factor explains the high COE in all three simulation cases. Moreover, compared with the current highly subsidized electricity production cost in Saudi Arabia, i.e., $0.036/KWh [or to the electricity tariff rate of 5 Halalas per KWh ($0.0133/KWh) for the residential sector in KSA], the COE of PV systems remains singularly high. A joint study by King Saud University and Saudi Electricity Company using PVSYST and SUNNY design programs confirms this fact. It has been found that the COE for a grid connected 50MW solar PV station is even higher, ranging between $0.216 and $0.24 per KWh according to weather conditions in Riyadh.[34] Thus, unless supported by appropriate policies or incentives, such deployments are not likely to be widely adopted.

Concentrating Solar Power (CSP)

Based on the availability of sites with high DNI – superior or equal to 2,000 KWh/ m^2/y –it has been estimated that CSP technology in Saudi Arabia has the potential to yield 124,560 TWh/year.[35] This represents 644 times the total consumption

33. CO_2 emissions are reduced by 24 percent (724 tons/year), corresponding to saving 24 percent of total fuel consumption in the reference scenario (diesel only system). See S.M.Shaahid and I. El-Amin, "Techno-Economic Evaluation of Off-Grid Hybrid Photovoltaic-Diesel-Battery Power Systems for Rural Electrification in Saudi Arabia – A Way Forward for Sustainable Development," *Renewable and Sustainable Energy Reviews* 13 (2009): 625-633.

34. E. Al-Ammar and A. Al-Aotabi, "Feasibility Study of Establishing a PV Power Plant to Generate Electricity in Saudi Arabia from Technical, Geographical, and Economical Viewpoints" (paper presented at the International Conference on Renewable Energies and Power Quality, Granada (Spain), March 23-25, 2010).

35. This represents the economic CSP electricity supply potential in KSA, see note 24 in Bahrain

of electricity in Saudi Arabia in 2009. It reflects large land availability and high values of DNI in the country; consequently, CSP can be considered among the most suitable solar technologies for use in Saudi Arabia.

Given that Saudi Arabia has long coasts, it has been estimated that the kingdom has a ‘coastal CSP potential’ of 2,055 TWh/year equivalent to 32 GW capacity potential which is enough to produce 144 billion cubic meters per year of solar desalinated water. This potential represents 142 times the total water production of Saudi Arabia in 2009.[36]

Surprisingly, the technical and economic feasibility of CSP applications were not thoroughly investigated in the Kingdom. Apart from an early R&D project conducted by KACST and the Federal Research and Technology of Germany in 1982 in the Solar Village to explore the feasibility of solar thermal electricity production, no specific case studies have been carried out.[37]

Wind Energy

In many locations, annual mean wind speed in Saudi Arabia exceeds 4m/s at a height of 20m. With 1,789 of full load hours per year (wind duration), the country has the second highest wind electricity performance indicator in the GCC region, after Oman. Such wind characteristics are considered to be appropriate for electricity production and should yield economically viable wind energy. In fact, wind energy potential in the Kingdom was estimated to yield 20 TWh/year of renewable energy-based electricity. [38]

chapter and German Aerospace Center (DLR), *Concentrating Solar Power*, 56; in this report, Direct Normal Irradiance (DNI) was estimated to be 2,500 KWh/m^2/year.

36. In 2009, the total consumption of electricity in KSA was 193,472 GWh and total water production reached 1,013.1 million m^3; these statistics are for 2009 and are from ECRA annual reports 2009 available at: http://www.ecra.gov.sa/Home.aspx; figures for the CSP water desalination potential are from W.E. Alnaser, F. Trieb and G. Knies, “The Potential of Concentrated Solar Power in the GCC Countries,” in *Proceedings of ISES World Congress 2007 - Solar Energy and Human Settlements*, edited by D.Y.Goswami and Y. Zhao, 2009; the yearly volume of desalinated water yielded from the coastal CSP potential are the author’s estimation.

37. The Saudi-German solar thermal project consisted of two solar concentrators acting as a heat source for Stirling engines. These heat engines were used to convert the collected solar thermal energy into mechanical energy in order to drive 2X50KW electric generators. For more information on this, see Alawaji, “Evaluation of Solar Energy Research and its Applications in Saudi Arabia.”

38. German Aerospace Center (DLR), *Concentrating Solar Power*, 56-57, and W. E. Alnaser and N. W. Alnaser, “Solar and Wind Energy Potential in GCC Countries and Some Related Projects,” *Journal of Renewable Sustainable Energy* (2009).

For the identification of high-potential areas for wind applications in Saudi Arabia, multiple studies have used wind speed data recorded between 1970 and 1982 at 20 meteorological stations that cover the whole of the country. A study by the Center for Engineering Research of King Fahd University of Petroleum and Minerals (CER-KFUPM) indicates that the Kingdom has two vast windy regions along the Red Sea and the Gulf coastal areas. Nordex wind turbines of 2,500, 1,300 and 600 KW of rated capacity were considered to calculate the potential electricity output and the cost per KWh generated by these systems at the different locations. The analysis showed that for all three wind systems (N80/2500; N60/1300; N43/600), Yanbu yielded the maximum power (4,941,487.2; 2,636,062.2; 1,295,196.5 KWh, respectively), followed by Qaisumah and Dhahran, whereas the least potential was registered for Nejran (1,639,959.3; 939,512.0; 468,969.0 KWh, respectively), slightly surpassed by Bisha and Tabouk. On the other hand, the minimum values for the COE were obtained for the following location-turbine combinations: Yanbu-N80/2500: $0.0234/KWh; Qaisumah-N80/2500: $0.0256/KWh; Dhahran-N80/2500: $0.0273/KWh; Yanbo-N60/1300: $0.0295/KWh; Turaif-N80/2500: $0.0302/KWh; Badana-N80/2500: $0.0304/KWh; Qaisumah-N60/1300: $0.0316/KWh; Dhahran-N60/1300:$0.0340/KWh; Turaif-N60/1300: $0.0370/KWh; Al-Wajh-N80/2500: $0.0372/KWh.[39]

These results show that wind electricity generation – without storage – is competitive when compared with diesel-only generation (Cf. results from hybrid PV-diesel energy studies mentioned earlier), which makes utilization of wind energy in hybrid systems attractive to replace or supplement diesel-produced power. Indeed, Saudi Arabia Electricity Company has developed wind-diesel hybrid systems for remote villages (Al Oweida wind study), while studies were conducted by CER-KFUPM to assess the technical and economic potential of different hybrid Wind-PV-Diesel energy systems to meet the load requirements of residential or commercial buildings in Dhahran.

For instance, different alternative systems were considered for a typical air-

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39. The COE was calculated using the capital cost, investment cost, operation and maintenance cost, depreciation, inflation rate, and interest rate. See S. Rehman, T.O. Halawani and M. Mohandas, "Wind Power Cost Assessment at Twenty Locations in the Kingdom of Saudi Arabia," *Renewable Energy* 28 (2003): 573-583. A further analysis comparing the economic viability of a 30MW wind farm project for five locations in Saudi Arabia indicated that only Yanbu and Dhahran would be suitable for harnessing such wind energy. In this exercise, Al-Wajh was ranked in third position. Average wind speeds in these locations are 5.10, 4.72, and 4.10 m/s, respectively. See S. Rehman, "Prospects of Wind Farm Development in Saudi Arabia," *Renewable Energy* 30 (2005): 447-463.

conditioned supermarket, with an annual (pre-defined) electrical load of 620,000 KWh. Namely, a wind-diesel energy conversion system, consisting of 30 10KW turbines, a battery storage and back-up diesel generator(s) was found to present the optimal solution where only 14 percent of the load requirement has to be provided by the diesel back-up system and 78 percent of its operational hours are saved. Similarly, with the three days storage system, the diesel system would contribute only 19 percent of the building's annual load, whereas it would have to contribute up to 40 percent if the battery storage is eliminated.[40]

No specific cost of electricity (COE) was calculated in this study. However, in a subsequent investigation, other hybrid solutions were proposed where wind turbines, PV panels and diesel generators were combined in different ways – using NREL HOMER software – to assess their viability. In particular, in case of a hybrid 300KW wind-175 KW diesel system, without storage, the COE was found to be as high as \$0.193 per KWh, compared with \$0.087 /KWh in case of diesel-only generation system, when diesel price is \$0.1 per liter. Nevertheless, other combinations yielded more attractive electricity costs, namely a hybrid 100KW wind-175 KW diesel generation system where, wind accounts for 25 percent of the total building load, and the COE does not exceed \$0.121/KWh. Furthermore, the least price for a hybrid PV-diesel system was obtained for a combination of a 40KW PV-175 KW diesel system and amounted to \$0.130/KWh, with a RE fraction of only 13 percent of the total load. Similarly, the least COE for a hybrid Wind-PV-diesel system was obtained for a 175KWdiesel-100KWwind-40KWPV system, where RE penetration is 24 and 12 percent, respectively, and the COE is \$0.154/KWh.[41]

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40. The use of hybrid system is dictated by the intermittent nature of winds as well as their variable speeds. Turbines do not produce energy unless the speed of wind is equal or higher than their cut-in wind speed, which generally ranges between 3.5 and 4.5 m/s. Studies indicate that in Dhahran the wind speeds are less than 4 m/s for about 35 percent of the time during the year. This implies that a stand-alone Wind Energy Conversion System installed at Dhahran will not produce any energy for about 35 percent of the time. Batteries will then have to enhance the WECS productivity. See M. A. Elhadidy and S. M. Shaahid, "Role of Hybrid Wind-Diesel Power Systems in Meeting Commercial Loads," *Renewable Energy* 29 (2004): 109-118

41. The author specifies that in the hybrid 175KWdiesel-100KWwind-40KWPV system, the total capital cost is \$647,000, 75 percent of which is due to the wind and solar equipment; however, this system allows a reduction of 44 tons of CO_2 emissions annually. See S.M. Shaahid, "Review of Research on Autonomous Wind Farms and Solar Parks and Their Feasibility for Commercial Loads in Hot Regions," *Renewable and Sustainable Energy Reviews* 15 (2011): 3877-3887. The article gives a good overview of wind research by CER-KFUPM in Saudi Arabia.

On the potential of grid-connected wind energy conversion systems, a simulation study conducted for a 20MW onshore wind farm installed in the eastern region of Saudi Arabia has concluded that such deployment is both technically and economically feasible and requires due attention from investors and policy-makers. Using Resoft WindFarm software and considering 10 Vestas turbines of 2MW each (V80-2000) to be deployed in Juaymah, the study showed that the proposed wind farm – with a capacity factor of 33 percent – could generate 59 GWh annually at an electricity price of $0.029/KWh.[42]

In summary, Saudi Arabia has enormous potential for exploiting solar energy if the capital cost of this form of energy is made competitive in the mid term with conventional and other renewable sources for power generation.[43] At the present time, however, because electricity prices in the Kingdom do not reflect the true production costs, the economics of RE technologies (solar in particular) are significantly disadvantaged when compared to fossil fuels-based generation.

As in all GCC countries, electricity demand in Saudi Arabia surges in the summer months; such peaks occur at times when the country is exposed to high insolation rates (both GHI and DNI), generally between 11 am and 3 pm. In Dhahran, both GHI and wind speed are highest during the summer months, which boosts its potential for RE power generation.[44] This factor is favorable for usage of solar/wind based electricity to meet the peak load requirements.

More generally, studies affirm that the Kingdom is also endowed with a substantial wind regime; in particular, it has been shown that wind energy can be exploited in reducing fuel consumption and GHG emissions, and in extending the life of diesel-based electricity systems. In remote areas where diesel generation or connection to the grid remains an expensive option, wind hybrid energy systems can prove to be beneficial.

Nevertheless, the importance of using renewable energy in Saudi Arabia seems

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42. S. Rehman, A. Ahmad and L.M. Al-Hadhrami, "Development and Economic Assessment of a Grid Connected 20MW Installed Capacity Wind Farm," *Renewable and Sustainable Energy Reviews* 15 (2011): 833-838. The study confirms the availability in the region of high wind speed of 5.69m/s at 40m above ground level on annual basis.

43. Some other studies put forward the geothermal energy resources of Saudi Arabia, e.g., H.M. Taleb, "Barriers Hindering the Utilisation of Geothermal Resources in Saudi Arabia," *Energy for Sustainable Development* 13 (2009): 183-188; however, compared to solar and wind energy, the potential economic profit from the Kingdom's geothermal energy is considered to be small and not cost-effective for exploitation in Saudi Arabia. See O. Alnatheer, "The Potential Contribution of Renewable Energy to Electricity Supply in Saudi Arabia," *Energy Policy* 33 (2005): 2298-2312.

44. Shaahid, "Review of Research on Autonomous Wind Farms and Solar Parks."

not to be confined to meeting demands in remote areas; other RE applications too have been researched. Besides, keen interest has been expressed in RE Research and Development (R&D) activities, both in Saudi Arabia and abroad, and multiple initiatives and programs have been conducted or funded. These are described in the following section.

Research and Development (R&D)

Background

We can clearly identify two phases in the RE R&D activities carried out by Saudi institutions. The first phase, from the mid 1970s to mid 1990s, was mainly dominated by scientific research with no involvement of the Saudi industrial sector. The second phase, manifest for the few last years, is marked by strong involvement of the private sector.

The Energy Research Institute (ERI) of the King Abdulaziz City for Science and Technology (KACST) has made progress in the use of solar energy equipment (PVs) with several experimental applications of solar technologies carried out through actual field studies at remote sites. Two major international joint programs – conducted by ERI in collaboration with the US and Germany – have assisted in the establishment of a series of research studies and pilot projects; it is estimated that from the mid-1970s to the mid-1990s, at least $200 million was invested in such programs.

Solar Energy Research American Saudi (SOLERAS) was established in 1975 in cooperation with the US and was directed towards demonstration projects such as solar electricity generation and decentralized usage (solar village project - 350 PV energy capacity), water desalination (Yanbu pilot plant and Sadous Reverse Osmosis unit), agricultural applications (solar dryers), and air cooling systems (solar cooling laboratories).

In general, it was concluded that, in addition to the capital cost, the overall operation and maintenance costs proved to be high due to natural factors (dusty environment with low rainfall), technical limitations (thermal fatigue of some components or water penetration inside the modules), or a human factor (lack of proper experience). It was also recommended that further research be done on solar energy devices, basic coating materials, or polycrystalline silicon and non-crystalline silicon material so to enhance their performance in local conditions.

However, through the continuous monitoring of these solar projects and the efforts to maintain or increase their performance, "the experience acquired [by the ERI, Saudi universities and local industry] has proved to be significant to the understanding, maintenance and advancement of the technology,"[45] SOLERAS concluded in 1997.

The second major research program is Hydrogen from Solar Energy or HYSOLAR. This program was contracted with Germany and concentrated on solar-based production of hydrogen. It investigated how the efficiency of PV plants and the solar-based production of hydrogen can be improved. HYSOLAR began in 1986 and ended in 1995 and enabled ERI researchers to gain professional experience. Besides, studies confirm that the R&D work on Phosphoric Acid Fuel Cells (PAFC) using hydrogen has successfully progressed in Saudi Arabia. Work on issues such as acid management techniques, control of leakage of hydrogen gas and intermixing of hydrogen and air in the cells of the stack due to lack of electrolyte in the matrix, led to an improved design and fabrication of the 1kW PAFC stack. This learning was considered valuable to improve electricity generating modules of 10 to 50 KW for power utility applications in remote areas of Saudi Arabia.[46]

Both SOLERAS and HYSOLAR programs involved international as well as Saudi research and industrial institutions and paved the way for further local R&D in the field of renewable energy applications conducted by ERI-KACST and/or other Saudi universities.

New R&D Activities and Research Centers

Following the Kingdom's recent socio-economic expansion and related growing consumption of energy, interest in alternative sources, such as RE and nuclear, has been renewed.

In this context, new research initiatives in the Kingdom were recently undertaken by or in collaboration with Saudi public and private institutions. The participation of local and international companies in this new phase of RE exploration stems from the need to add an industrial development aspect to research where explored RE technologies are adapted to local capabilities, needs and conditions. This is

45. For instance, King Faisal University in Dammam, King Abdulaziz University in Jeddah, King Fahd University of Petroleum and Minerals in Dhahran, and King Saud University of Riyadh have joined KACST research program to establish solar cooling labs – each had to be equipped to conduct design, analysis, system integration and experimentation on solar cooling concepts. See F.S. Huraib, S.M. Hasnain, and S.H. Alawaji, "Lessons Learned from Solar Energy Projects in Saudi Arabia," WREC (1996), and Alawaji, "Evaluation of Solar Energy Research and its Application in Saudi Arabia."

46. Ibid.

welcome, as in the absence of local strategies, past R&D activities did not translate into local RE industries.

New testing facilities, small-scale deployment, or international cooperation programs have been initiated in the last few years, and they involve new players and new RE technologies. For instance, in addition to KACST and Saudi academia, energy companies like ARAMCO, SEC, Areva Solar, Shoya Shell Solar and others are leading solar R&D projects in the Kingdom. Similarly, new laboratories like KFUPM CoRE-RE or KAUST Solar and Alternative Energy Science and Engineering Research Center have been established.[47] RE applications under investigation are as varied as solar hydrogen, solar desalination, CSP, as well as silicon and non-silicon based thin film PV technologies or wind feasibility projects.

Among the research programs that have been initiated is the KACST-IBM joint research project on how to make water desalination technology more energy efficient. The two entities have been collaborating since 2008 to set up a center of excellence to work on nanotechnology and develop the Saudi Arabia-based Solar Village and improve its performance. A solar desalination research project was devised to develop novel membrane technology and photovoltaic materials – ultra-high concentrator photovoltaic (UHCPV) – that will help build and power a 30,000 cubic meters per day solar desalination plant in Al Khafji.[48] The project, which should constitute the

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47. In 2007, the Ministry of Higher Education established the Center of Research Excellence in Renewable Energy (CoRE-RE) as part of the Research Institute at KFUPM to further the scientific/technological development of renewable energy in the Kingdom and to promote linkages with related industries. The main research areas of the CoRE-RE are Hydrogen, Methanol and Fuel Cells, Advanced Energy Storage, Electrical and Control Systems for Wind and Solar Energies, and Economics of Solar and Wind Energies; more on CoRE-RE research areas on: http://corere.kfupm.edu.sa/research.html. The Solar and Alternative Energy Science and Engineering Research Center of the newly-established King Abdullah University for Science and Technology (KAUST) is initiating international cooperation programs that address materials, device and processing problems; see: http://www.kaust.edu.sa/research/center-solar.aspx. Also KAUST-Water Desalination and Reuse Center (WDRC) is conducting research on solar desalination; Outside Saudi Arabia, KAUST is funding a research center at Stanford University called "The Center for Advanced Molecular Photovoltaics" to focus on searching new organic solar cells, enhancing their actual efficiency from 6.5 percent to 15 percent, and extending their life from one year to 10 years or more. It was announced that the grant amounts to $25 million over 5 years; see http://news.stanford.edu/news/2008/june11/saudi-061108.html

48. Under this multi-year agreement, the work will be conducted between teams working at IBM laboratories in Zurich, Switzerland; Almaden, California; Yorktown Heights, New York; and the KACST/IBM Nanotechnology Centre of Excellence in Riyadh, Saudi Arabia. Please refer to "Saudi Research Organization Creates Nanotechnology Centre with IBM to Drive Innovation

largest water desalination plant by solar energy in the world, was expected to be completed in 2012, but may be delayed till the end of 2013. Nevertheless, according to Prince Dr. Turki Bin Saud Bin Mohammed, Vice President of KACST for Research Institutes, finding technical solutions for water production at low costs remains an economically strategic objective of the Kingdom.

In this context, research on solar Adsorption Desalination (AD) is being jointly conducted by KAUST Water Desalination and Reuse Center (WDRC) and the National University of Singapore. The AD project is based on solar thermal evaporation where vapor is captured through its high absorption onto the pores of the adsorbent material (thanks to its high vapor uptake affinity); In the AD cycles, cooling power is produced in the evaporator while potable water is produced in the condenser. In addition to numerical simulation and site performance, the project leaders are also searching adsorbent materials and development of combined cycles with MED or MSF desalination technologies.[49]

Indeed, according to Saudi researchers, advances in the field of solar-powered desalination make the incorporation of solar thermal assemblies into multi-stage flash (MSF) an area worth exploring. However, parabolic troughs, evacuated tubes, and heat-pipe solar collectors should also be designed and tested in Saudi Arabia climate conditions.[50]

Interest in solar thermal energy development in the Kingdom was also expressed by the Bin Laden Group and Areva Solar, the renewable energy group of the French nuclear energy company, AREVA. Back in January 2011, they announced the setting up of a pilot project to test the technology at New Energy Oasis (NEO) Park of KAUST.[51]

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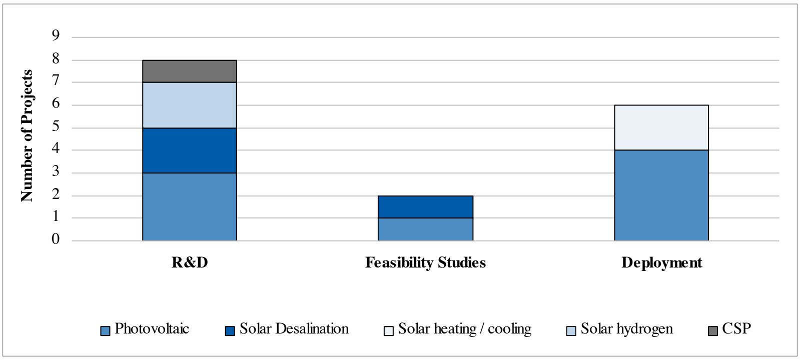
in Sustainable Resources" in http://www.ibm.com/news/bh/en/2008/02/25/m868295b23805z63.html and http://www.zawya.com/printstory.cfm?storyid=ZAWYA20081027042204&l=042200081027 ; For KACST IBM Partnership, see "IBM, KACST research solar-powered desalination" April 9, 2010. http://www.filtsep.com/view/8693/ibm-kacst-research-solarpowered-desalination/ and "IBM, KACST To Develop Solar Powered Desalination Plant" http://waterwastemanagement.cleantechnology-business-review.com/news/ibm_kacst_to_develop_solar_powered_desalination_plant_100409/

49. Address of the Prince Dr. Turki Bin Saud Bin Mohammed at the Saudi International Conference for Water Technology 2011, reported in "Solar Desalination in KSA by 2013," *Saudi Gazette,* November 22, 2011http://www.zawya.com/printstory.cfm?storyid=ZAWYA20111122051829&l=051800111122 ; More information on the AD technology, KAUST-NUS project and its current key findings can be found at http://wdrc.kaust.edu.sa/Pages/Adsorption-Desalination.aspx

50. Alawaji, "Evaluation of Solar Energy Research and its Application in Saudi Arabia."

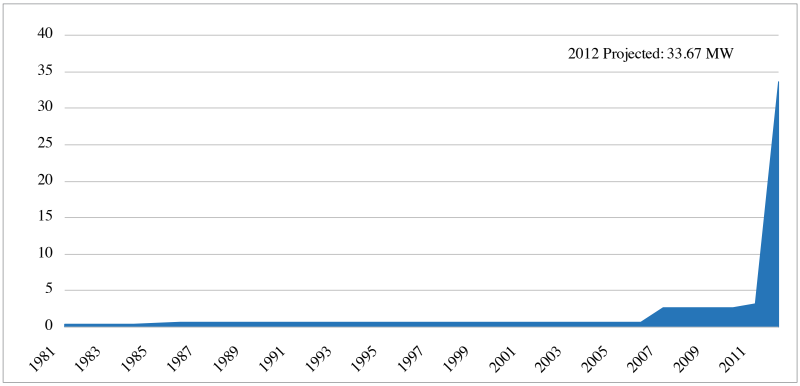
51. The announcement was made by Anne Lauvergeon (chief executive, Areva), in "Oil Giant Saudi

Number of Renewable Energy Projects in Saudi Arabia per Nature and Technology (up to 2012)



Source: Author's calculation

RES Projects KSA - Cumulative Capacity (MW)



Current RES installed capacity amounts to 3.17 MW. Three more RES projects are expected to materialize in 2012 that will amount to an additional 30.5 MW capacity. Source: Author's calculation

Other R&D activities in NEO Park include evaluating the performance of different photovoltaic modules under high temperature conditions, and the influence of sandstorms on their efficiency. For instance, Kaneka Corporation, a thin-film

Arabia Looks to Alternative Energy," AFP, January 25 2011 available at http://www.google.com/hostednews/afp/article/ALeqM5itqKHsX-s5XsPJDuP8YEO4GxPV2w?docId=CNG.8c338e3b1bec49650ef90f296bedf8dc.121; however, it is not clear whether such deployment has materialized since then.

silicon photovoltaic modules manufacturer in Japan, has installed a 10 KW thin-film amorphous silicon PV capacity at the research park. The system consists of 140 PV modules, half of which includes a surface treated with a special coating to protect it against sandstorms, and it is being connected to the grid. Measurements were expected to continue over a period of some years under Saudi Arabian climate conditions.[52]

Similarly, as part of its road map for the installation of solar power pilot plants,[53] ARAMCO aims to identify the best PV and CSP performing technologies under local conditions. In 2010, it commissioned Oman-based Phoenix Solar LLC, a subsidiary of Phoenix Solar AG, and Naizak Global Engineering to install a photovoltaic testing field designed to analyze different module technologies at its headquarters in Dhahran. A year later, it commissioned the same companies to build a solar plant of 3.5 MW adjacent to the King Abdullah Petroleum Studies and Research Center (KAPSARC) on the outskirts of Riyadh.[54]

In the same context, a partnership between ARAMCO and Japan's Showa Shell Sekiyu Solar was inked in 2009 in order to study the potential of power generation using Showa Shell Solar's Copper-Indium-Selenium (CIS) panels. This technology is thought to be more durable in high Saudi Arabia temperatures than conventional silicone-based photovoltaics. The building of 10-megawatt capacity solar power plants in locations with no access to the grid will serve as a first step to developing a Kingdom-wide solar energy strategy.[55]

It is worth mentioning here that, during the summer of 2011, a pilot plant with a 500 KW capacity was commissioned on the island of Farazan to evaluate the technology with a view to its later expansion. The plant is being implemented under a cooperation agreement between the Saudi Electricity Company (SEC) and Shoya

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52. More on Kaneka at: http://www.kaust.edu.sa/media/pressreleases/kaneka.html

53. ARAMCO has also announced that it plans to install large-scale solar power plants in the gigawatt-range from 2014 onwards.

54. Naizak News, "Naizak to build Solar Power Plant for Saudi Aramco at KAPSARC," February 14, 2011 available at http://www.naizak.com/News/2011/110214_PM_Saudi_Aramco.html and Reuters, "Phoenix Solar AG to Build Solar Power Plant for Saudi Arabian Oil Company in Riyadh," February 14, 2011 available at http://www.reuters.com/finance/stocks/PS4G.DE/key-developments/article/2085844

55. Shoya Shell Solar 2-square-meter panels are capable of generating 80 watts of power; "Showa Shell Eyes Solar Project in Kingdom," Saudi Aramco Jobs, September 5, 2009: http://www.jobsataramco.eu/98/showa-shell-eyes-solar-project-in-kingdom.htm, "Showa Shell, Saudi Aramco to Form Solar Power JV," Reuters, June 24, 2009: http://in.reuters.com/article/2009/06/23/showashell-idINBNG49124320090623

Shell, which will own it for up to 15 years, after which the assets will be transferred to SEC. However, although SEC has enough land to expand such deployment upto 7 MW of capacity, the company insists that government support is primary for such expansion. [56]

R&D and pilot projects of this kind may go a long way in boosting innovations in the field of solar energy which should lead Saudi Arabia to identify and develop the technologies and industries that are most relevant to its geographical conditions, energy needs, and market development. However, for R&D to be effective in disseminating and commercializing renewable energy technologies there should be interaction between research centers, local industries, policy-makers, and investors. The knowledge gained in laboratories or embedded in imported technologies will not be widely utilized unless such linkages exist and mature. In this sense, Saudi public and private authorities should demonstrate commitment for such a renewable energy system – namely solar – to be put in place. The scalability of this economic sector offers the possibility for public, private, local or international investors and industries to play a role in its development.

In this sense, an increasing number of voices are specifically advocating the deployment of RE technologies in Saudi Arabia. Compared to other alternatives, solar energy is considered to be particularly suitable for the Saudi context as all its major raw materials are abundant locally.[57]

Photovoltaic Manufacturing

Saudi Arabia offers several advantages for solar manufacturing projects. With access to capital, low energy prices, and a potentially large emerging market, it is an attractive location, especially for CSP and upstream PV manufacturing activities such as the production of poly-silicon, ingots and wafers.[58]

In a recent development, Mutajadedah Energy Co. (MEC), a local company owned by Swicorp Joussour Co. (SJC) and Chemical Development Co. (CDC)

56. Reuters, "Showa Shell, Saudi Electricity Start Saudi Solar Plant," August 8, 2011.
57. Othman Al-Khowaiter, former Vice President of Saudi ARAMCO, "Investing in Renewable Energy," *Arab News*, February 5, 2011; and Mohamed H. Al-Mady, "Alternative Energy Holds Promise," *Arab News*, May 25, 2010.
58. According to APRICUM, three polysilicon manufacturing projects, accounting for a total output of 16,500 tons per year, are currently being developed. See "Saudi Arabia Plans to Enter Large-scale Solar Power Generation" in http://www.apricum-group.com/en/media/news-overiew/emerging-markets/179-apricum-saudi-arabien-solarstrom-solar.html

Incorporated, and KCC Corp. of Korea (KCC) set up Poly-silicon Technology (PST), a joint venture to construct a plant in Jubail II, along the Gulf coast, that will produce 3,350 metric tons of solar grade poly-silicon annually by 2014. PST intends to expand the plant's annual capacity to 12,000 metric tons as well as continue further downstream into the manufacturing of ingots and wafers by 2017. Such a private sector initiative is in harmony with the local market and raw materials. It is also considered to be aligned with the Kingdom's long-term energy plans and institutions' goals, such as that of King Abdulla City for Atomic and Renewable Energy (KA-CARE). [59]

Although photovoltaic technology must undergo a host of processes before it can actually be used to generate solar power, and Saudi polysilicon could end up on a global market rather than stimulate domestic solar production, supporting local manufacturing of PV technology materials such as polysilicon would later promote domestic solar industry, increase the local private sector's participation in the development of the Saudi market, and establish a technological base that is aligned with the global trend to develop solar technologies.[60]

Pending the development of a local solar manufacturing and installation industry, and in the context of globalized trade flows, it is expected that the majority of the PST plant's production will be sold to China and Taiwan, where polysilicon is processed into ingots, manufactured into wafers and cells, and eventually assembled into modules to generate power.[61] However, the Kingdom's National Industrial Clusters Development Program (NICDP) is pushing towards more downstream

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59. This was expressed by former governor of Saudi Arabian General Investment Authority (SAGIA) to Siraj Wahab, "A Contract to Set up a Poly-silicon Plant in Jubail to Manufacture Solar-energy Cell Material Was Signed on Sunday," *Arab News*, February 28, 2011; prior to that First Energy Bank announced in 2009 that it would build a $1 billion polysilicon plant by 2013 in the Jubail Industrial City in Saudi Arabia with a production capacity of 7,500 tons per year; however, a year and a half later, the project was still in the planning phase. See First Energy Bank, Press Release, November 17, 2009.

60. In Saudi Arabia, Al-Jazirah Solar Systems and Electronics Factory and BP Solar Arabia Ltd. are importing ready-made solar cells and then assembling photovoltaic modules for electricity generation. These modules are used for lighting, water heating, drinking/irrigation water pumping, cathodic protection for (oil, gas, water) pipelines, telecommunications, etc. Siemens is also planning to establish a PV factory in Saudi Arabia and Al-Afandi Establishment has started working in the field of solar thermal technologies as well as the manufacturing of PV modules, but their products need some time for development before commercialization. See Saleh A. Al-athel "Solar Energy in the Kingdom of Saudi Arabia."

61. Maria Gallucci, "Saudi Arabia's Solar Ambitions Still Far Off, Even With New Polysilicon Plant," Reuters, March 9, 2011: http://www.reuters.com/article/2011/03/09/idUS100792642520110309

silicon industry; accordingly, a mid- to long-term annual capacity of 12,000 tons of solar grade and semiconductor grade polysilicon is projected to supply the production of ingot, wafers, cells or solar grade glass for export.[62]

Nonetheless, as polysilicon manufacturing is yet another highly energy-intensive industry, Saudi authorities ought to advance RE deployments, namely photovoltaic panels, in order to mitigate the electricity consumption and GHG emissions related to these industrial processes. This way, the Kingdom will compensate environmental consequences of cheap access to energy for its future silicon industry, by boosting domestic solar installation market.[63]

Targets, Policies, and Market Potential

Subsidies

As mentioned earlier, heavy subsidies in the power sector in Saudi Arabia are disadvantaging RE sources and suppressing large deployments of their technologies. It is a widely shared opinion in the Kingdom that such subsidies were and still are leading to excess electricity demand and to high-energy intensity levels that not only put pressure on the country's reserves of fossil fuels but also increase the burden on the government finances. [64]

Based on this view, the Saudi National Energy Efficiency Program (NEEP) has conducted through the last decade a master plan study for energy conservation in the power sector. The target is to accomplish 30 percent reduction of electricity-GDP intensity (electricity consumption per GDP) by 2030 compared with 2005 level and a 50 percent reduction of peak demand growth rate in 2015 compared with the average in 2000-2005. In particular, NEEP has developed energy audits and load management programs (it has shifted 400 MW from the 1-5pm peak load period), energy efficiency standards and labels, and building codes. [65] However, the

62. Joe Avancena, "Saudi Arabia Fosters Production of Solar Energy Products," *Saudi Gazette*, October 12, 2011.

63. According to experts, as Saudi Arabia "can generate electricity really inexpensively, locating [a polysilicon] plant there, has more to do with its "cheap and dirty" electricity than its potential market for solar power." Refer to Gallucci, "Saudi Arabia's Solar Ambitions Still Far Off."

64. For instance, Al Falih, Speech at the MIT Club of Saudi Arabia Dinner, and excerpts from *Financial Times*, see note 20; Trabulsi, Lecture on Renewable Energy, see note 19.

65. Established in the year 2000, NEEP works with five ministries and three companies (ARAMCO, SABIC and Saudi Electricity Company) to promote energy efficiency. See NEEP website: http://www.neep.org.sa/en

impact of NEEP programs remains limited, and there is still a need to improve the energy efficiency of new residential and commercial buildings as well as enhance public awareness through campaigns.[66]

At any rate, such measures should also be supported by the adoption of new electricity tariff rates so to achieve less wasteful patterns of consumption. For instance, when one considers that the residential sector accounts for the biggest share of electrical consumption in Saudi Arabia, and that it is put in the category of primary tariff bracket – i.e., only SR0.05 per KWh ($ 0.013/KWh) as per latest reports – it is obvious that such tariff structure is not optimal for electricity conservation and cannot be sustained in view of the Kingdom's population growth and its future demand.[67] Similarly, power production subsidies directly constitute the biggest barrier to the development of renewable energy sources in Saudi Arabia. The present cost of conventional electricity in the Kingdom renders it impossible for RE electricity to be competitive.[68]

For these reasons, a policy and culture of rational and efficient use of energy, triggered by tariff revision, could be the driver for renewable energy development. Savings generated from increasingly energy efficient systems can be used to finance progressive expansion of a long-term sustainable and renewable energy system.

Targets

In an attempt to explore the use of RE technologies in the power sector, ECRA commissioned in 2009 a project proposal for a national renewable energy plan (NREP) for Saudi Arabia.[69] The proposal plan included studying the feasibility of RE applications in the Kingdom, introduction of RE targets with strict deadlines, establishment of implementation bodies, economic considerations of tariff

66. For instance, in May-June 2011, the Saudi Energy Exhibition 2011 – a platform for KSA Industrials to find energy efficient solutions – featured in conjunction with the main event an international conference on energy conservation called the Electricity Efficiency Forum. Similarly, on April 30, 2011, the German-Saudi Arabian Liaison Office for Economic Affairs based in Riyadh also organized a one-day symposium on energy efficiency and sustainability in the construction sector.

67. *Saudi Gazette*, "Low Tariff Bridles Power Revenue in Saudi Arabia," September 18, 2011.

68. It is worth recalling here that in 2009 the average cost of a unit of electricity (1 KWh) in Saudi Arabia was SR0.138 ($0.0368), and that it is sold at 0.12 to industrials; ECRA, *Activities and Achievements of the Authority in 2009*, 29 and 32.

69. "Saudi Policymakers Consider Alternatives for Renewables Development at LEI led Workshop" (Report of a workshop led by London Economics International LLC in June 2009, available at http://www.londoneconomics.com/pdfs/june09-pr-saudi-workshop.pdf)

feeds evolution that could be enacted within a RE national plan perspectives, opportunities for Saudi market evolution and diversification, and the job prospects that RE could offer. In particular, it was estimated that with oil prices going up, RE electricity prices coming down, and a comprehensive regulatory framework in place, renewable sources could account for between 7 to 10 percent of KSA power output by 2020.[70]

In parallel, in the framework of the country's modernization efforts of the electricity sector, a new entity – Saudi Power Procurement Company (SPPC) – was planned as part of SEC's restructuring into a holding company. Hence, in a first reflection about NREP, Saudi authorities involved in this consultation considered that existing (or soon to be created) institutions like the MWE, KACST and SPPC should be adequate to follow up with the implementation of NREP in terms of promotion of renewables, coordination with academic input, or supervision of the renewables' procurement process.

Later, the establishment of the King Abdullah City for Atomic and Renewable Energy (KA-CARE) by a royal decree on April 17, 2010 underlined the necessity to oversee and optimize all stakeholders' efforts to push towards the implementation of a national RE development plan. On the other hand, putting nuclear and renewable energy policies under the supervision of one authority – namely KA-CARE – equally shows the importance given to nuclear energy in Saudi Arabia's alternative energy plans. According to the director of KA-CARE, the Kingdom could produce nuclear energy by 2020 and solar and wind energy within eight to 10 years.[71]

In any case, this decree certainly reflects the Kingdom's decision to preserve the hydrocarbon energy stream as a strategic export revenue source.[72] With this in mind, the vice-president for Renewable Energy at KA-CARE declared that in addition to providing the framework for renewable energy power generation, the authorities will focus on creating jobs through the establishment of local manufacturing activities within the solar value chain and that the development of

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70. AJ Goulding and Neil Bush, "Final Proposal for National Renewable Energy Plan for Saudi Arabia" (Presentation to stakeholders prepared on behalf of ECRA, December 12, 2009, Riyadh, Kingdom of Saudi Arabia, available at: http://www.ecra.gov.sa/upload/2nd%20workshop.pdf)

71. Hashem Yamani, Director of King Abdullah City for Atomic and Renewable Energy, in "Oil Giant Saudi Arabia Looks to Alternative Energy," alarabiya.net, January 25, 2011.

72. Ali Sayegh, Director General of World Renewable Energy Network, quoted in Siraj Wahab, "Experts Suggest Kingdom Develop Renewable Energy," *Arab News*, April 26, 2010; Also available at: http://www.menafn.com/qn_news_story_s.asp?StoryId=1093325998&src=MOEN)

solar energy in Saudi Arabia is expected to have a large impact on the Kingdom's future economic growth.[73]

Consistent with priorities and benefits repeatedly highlighted by Saudi experts and energy stakeholders in terms of gains from avoided fossil fuel use and development of local manufacturing of RE equipment, the implementation of the 2009 NREP was presented as essential "to provide potential investors with clear understanding of how they will get paid, how much, who will make the payment, and have confidence in commitment of authorities to renewables." In this context, the NREP recommends a procurement process where bids would be submitted for RE contract of 10 MW minimum and contract terms of 20 years for power purchase agreements.[74]

Indeed, in line with the independent power projects (IPP), the introduction of RE power purchase agreements for a minimum number of years and/or a minimum capacity (size in MW) will help build a market-led renewable energy sector. It will enhance the RE investment context in the Saudi RE energy market and incentivize developers to propose projects to the government with a full understanding of the tariffs on offer. In this sense, the purchase agreement supporting the solar energy projects could be output-based, where the level of support would differ according to the technology used by the project (PV, CSP or other). Subsequently, privately-financed projects in the area of solar energy generation should progress immensely, which should further attract international companies to position themselves in the Saudi market and prepare for market entry. [75]

However, it is important to emphasize that such prospects are unlikely to

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73. Khalid M. Al-Sulaiman, Keynote address at the Third Saudi Solar Energy Forum that was held in coordination with German Apricum Strategic Management Consultancy firm; quoted in M.D. Rasooldeen, "Peak Power Demand to Triple in Two Decades, Forum Told," *Arab News*, April 3, 2011. Some independent forecasts expect cumulative solar installments in Saudi Arabia to reach 14 GW by 2020. This, however, would eventually represent a staggering 20 percent of the country's projected power capacity by 2020, which is a very high target; see APRICUM, "Saudi Arabia Plans to Enter Large-scale Solar Power Generation."

74. Initially, the authorities should seek contracts of two to four GW of RE capacity by 2011, and issue referent prices by technology in early 2012 for a first procurement round between 2011 and 2014. Referent pricing would be used as a form of FIT in between procurement rounds; at the time of writing these phases – request for proposals and referent pricing for 2011-2014 – have not yet been achieved. More details on the NREP in Goulding and Bush, "Final Proposal for National Renewable Energy Plan for Saudi Arabia."

75. Freshfields Bruckhaus Derringer, *The Renewables Market in MENA - Opportunities and Challenges*, February 2010; and APRICUM: http://www.apricum-group.com/en/media/news-overiew/publications.html

materialize unless (costly) financial incentives are introduced, lead contracting authorities identified, and licensing and business set-up processes made definite for the private developers to invest in Saudi Arabia RE sector.[76] In the Saudi context, development of RE is likely to be driven only by the government or state-owned companies. It is probably for this reason that some ARAMCO officials have called for investments in solar energy from oil revenue; in their opinion, this will deliver more profitable economic returns than investing in other traditional fields and will pave the way for the growth of many domestic industries with plenty of employment opportunities.[77]

Human Resource Development

The solar power sector is relatively labor intensive, and large-scale development of solar energy would generate significant semi-skilled job opportunities, especially in the installation and maintenance of devices. The sector also benefits from low barriers of entry, ample space for technological improvements, and economies of scale.[78]

Based on solar PV statistics in leading countries such as Germany and the US, it is estimated that the sector creates at least seven permanent jobs per one MW installed of this technology.[79] These statistics, however, pre-suppose the existence of a strong industrial fabric that integrates all PV related manufacturing industries as well as installation and maintenance services.[80]

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76. It was expected that Saudi Arabia would establish a regulatory RE framework in the course of 2011. Announcements were made that the government would propose a support mechanism for solar power projects in the Kingdom that will implement a universal feed-in tariff. This mechanism was qualified as similar to the system used in California, USA. However, progress on this front might prove to be slow in Saudi Arabia, as – at the time of writing – the regulatory framework for such projects is still lacking. See Verity Ratcliffe, "Saudi Arabia to Unveil Tariffs for Solar Power," *MEED,* March 27, 2011.
77. Mohammed Ali Trabulsi, Saudi Aramco's executive director of pipelines, distribution and terminals; see note 19; and Ahmad Al-Khowaiter, Director of New Business Evaluation Department at ARAMCO, in "Kingdom Sees Surge in Solar Energy Output," Reuters, May 21, 2010.
78. NCB Capital, "Thinking beyond Oil, Renewable Energy and Opportunities in GCC," October 2009.
79. Renewable Energy Policy Network for the 21st Century REN21, *Renewables 2010 A Global Status Report,* 19 and 34; Report available at: http://www.erec.org/fileadmin/erec_docs/Documents/REN21%20GLOBAL%20STATUS%20REPORT%202010.pdf
80. All parts of the solar supply chain from silicon, crystallization, wafering, cell manufacturing and module production to fitting – which might include integration into buildings.

All the same, if we consider that peak demand in Saudi Arabia should hit 77.4 GW in 2020 and if the country maintains the 10 percent target of RE technologies in its energy mix by the same date,[81] then we can theoretically estimate the RE labor market should amount to 54,180 jobs in the solar photovoltaic sector.

Similarly, it is estimated that each one MW of solar heating should create 1.2 permanent jobs, which approximately corresponds to 1,430 m^2 of solar panels.[82] In case only solar water heating/cooling (residential, commercial and industrial) contributes to the 10 percent target, the sector would create 9,288 jobs. Moreover, according to experts from ERI-KACST, it has been proved that the manufacturing of solar water heaters is much cheaper in Saudi Arabia and its utilization is economically viable.[83]

It is clear that the availability of RES technical education and training is paramount to help build a solar energy sector. Therefore, a major effort is indeed needed to develop Saudi human resources, their knowledge, skills and professional experience.[84] Specific RE training programs should thus be designed to provide qualified manpower to answer market needs, which will equally promote national participation in a potentially dynamic future solar sector.

Such an endeavor is coherent with the Technical and Vocational Training Initiative that has been championed by the Ministry of Education and Learning, the Ministry of Higher Education, and the General Organization for Technical Education and Vocational Training (GOTEVOT) as an attempt to enhance employability at a national level.[85]

Furthermore, close cooperation between the Ministry of Education, GOTEVOT initiative, Saudi R&D centers and local industries should be encouraged by policy-makers to accelerate the acquisition of RES scientific knowledge. Another required strategy is to expand the private sector's participation in technical and vocational RES training. For instance, access to cheap, subsidized energy in Saudi Arabia can be offered to local and foreign energy-intensive industries in exchange for

81. As specified in the 2009 NREP and announced to the media in more recent statements.

82. By accepted convention, 1 million m^2= 0.7 GWth. Renewable Energy Policy Network for the 21st Century REN21, *Renewables 2010 A Global Status Report,* 22, 34 and 56.

83. Alawaji, "Evaluation of Solar Energy Research and its Applications in Saudi Arabia," 73.

84. Mohammed Ali Trabulsi, Saudi Aramco's executive director of pipelines, distribution and terminals, in "Experts Suggest Saudi Arabia Develop Renewable Energy," see note 19.

85. Saleh Al-Amr, "Creating an Industrial Labour Force in Saudi Arabia, Current Situation, Linkage with Industry and Future Expansion" (Presentation for the Saudi Energy Forum, Dammam, November 20, 2006). Salah Al-amr is Vice Governor for Development, GOTEVOT. The Saudi Energy Forum, http://www.saudienergyforum.com/

mandatory training and transfer of technical know-how to the Saudi labor force, thus promoting local content in the industrial sector.[86]

Renewable Energy Outlook

Socio-economic growth in Saudi Arabia is increasingly consuming its hydrocarbons, the country's main source of revenue.[87] The accompanying growth of power demand means that an increasing share of the oil is being burned domestically at subsidized prices to produce electricity, which means, besides waste, an increase in power consumption that may damage the balance of trade. Thus, reducing dependence on hydrocarbon power by shifting supply of electricity towards more sustainable sources constitutes a strategic imperative for the development of the power sector. In this sense, renewable energy sources, specifically the country's solar energy capital, can play a promising role and contribute to future energy production, in terms of both heat and electricity.

However, realizing that growth in electricity and water demand for the next 10 years will be significant, Saudi Arabia has been envisaging alternative sources to feed its future needs. In 2011, the Kingdom announced that it is planning to invest upto $100 billion to expand power generating capacity, including the construction of a nuclear plant and the deployment of 5GW of solar energy capacity by 2020.[88] Such RE deployment would eventually achieve a target of six to seven percent of the total projected capacity by that date. However, at the time of writing, it was not clear which legal framework the Kingdom would opt for to accompany such development.

Since the mid 1970s, the country has been aware of its massive solar and, to a lesser extent, other RE potential. Major energy stakeholders in the Kingdom are also

86. It was announced that the partnership between Showa Shell Solar and ARAMCO, described in the section on New R&D activities, also includes training of Saudi engineers at the Showa Shell solar energy plants, to ensure they gain knowledge and experience in the solar energy technology. Shoya Shell is partly owned by Saudi ARAMCO. See "Showa Shell Eyes Solar Project in Kingdom," "Japan Refiner Eyes Solar-Power Business in Saudi," http://www.channelnewsasia.com/stories/afp_asiapacific_business/view/438207/1/.html

87. In 2007, the hydrocarbon mining sector accounted for 50.5 percent of its GDP and 88.2 percent of its exports; in 1997, these figures were 32.9 percent and 88 percent, respectively. See GOIC, *Gulf Statistical Profile*, 2008.

88. "Saudi Arabia to Generate 5 Gigawatts of Solar Power," *Saudi Gazette*, May 6, 2011; "Saudi Arabia To Spend $ 100b on Clean Energy," *Saudi Gazette*, June 23, 2011; April Yee, "Solar Panels on Saudi Island are Small Step in Ambitious Project," *The National*, June 2, 2011; Avancena, "Saudi Arabia Fosters Production of Solar Energy Products."

aware of this potential, which has triggered a demand for studies and consultation services. All recommend and justify the integration of solar and wind in the energy mix and industrial fabric of the country.[89] Apart from the environmental paradigm – noticeably under-developed in the majority of these studies or discourses – rationalization of energy and optimization of its usage, diversification of the economy and job creation, tackling of subsidies and their negative impact on the government's finances or the wasteful consumption, were each in turn regarded as incentives or drivers for RE development in the Kingdom. Yet 35 years after it all started, no significant RE capacity is deployed in the country. One of the reasons is that all these efforts have been scattered. They may also continue to remain ineffective, unless integrated measures and policies are introduced.

In general, the core challenge facing the growth of solar energy is how to significantly reduce costs as fast as possible so that it becomes financially competitive. However, the fact that oil and gas are sold to power producers (mainly SEC) at subsidized rates, considerably below market prices, makes RE power generation particularly non-competitive in the Kingdom. So even with the costs of photovoltaic power coming down in the last few years, it still has to compete with electricity that is being artificially kept at a very low price.[90]

In this regard, even if it fails to address issues of energy subsidies or adopt new power pricing policies, Saudi Arabia should introduce specific financial incentives, like local credit system or RE subsidies, to encourage and enable the private sector and general public to access, own and operate solar-energy technologies. This should also lead to gradually increasing awareness about the benefits of utilizing

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89. In Saudi Arabia, although academic studies have shown a particularly high solar electricity tariff compared to conventional prices, it was recommended that the government support deployment of RE technologies through both feed-in-tariff and procurement processes. See, for example, Al-Ammar and Al-Aotabi, "Feasibility Study of Establishing a PV Power Plant to Generate Electricity in Saudi Arabia." Others recommend feasibility studies to be conducted and pilot plants – in sites with high solar potential – be developed and implemented in order to overcome the various aspects of RE adoption and technology transfer in Saudi Arabia. See S. Rehman, M.A. Bader S.A. Al-Moallem, "Cost of Solar Energy Generated Using PV Panels" (2007): 1843-1857; esp. 1856.

90. Othman Al-Khowaiter, former Vice President of Saudi ARAMCO, writes that "Comparing the cost of solar power generation in our country with the cost of our electricity generation from low-priced petroleum fuel is unreasonable. The comparison will be fair and acceptable only if the actual cost of solar power generation is compared with the cost of electricity generation calculated on the basis of the international price of petrol, not the low price in the Kingdom." see note 57. Petroleum is sold to the Saudi electricity production sector (mainly SEC) at the cheap rate of \$2.7-4.3 per barrel of oil equivalent (BoE) compared to export prices of around \$100. See Reuters, "Saudi Oil Exports Feel Threat From Within," October 15, 2011.

these sources of energy. In particular, solar water heating and cooling for domestic and large users of energy such as hotels, hospitals and industry, will contribute to notably reducing consumption of crude oil generated electricity.[91]

Strategic imperatives related to RE deployment in Saudi Arabia should also be about land development or how to develop the huge territory, including its remote areas, in a cost-effective way. Large parts of the Saudi population are not urbanized,[92] which adds to the challenges of electrification in terms of the costs of power transmission and losses due to large distances and constitutes a hurdle for the socio-economic inclusion and development of these communities. Thus, deployment of RE applications in these remote communities should be attractive as, for instance, photovoltaic technologies are particularly well designed for off-grid and rooftop applications and could present services equivalent to conventional solutions, while promoting a better control of grid extensions and contributing to energy diversification in the Kingdom.

Feasibility studies have shown that hybrid applications are reliable and cost effective; hence, such schemes could be adopted by the authorities to optimize the costly diesel-powered electricity in the country. Furthermore, in 2008, diesel units contributed 1.2 percent – 413.64 MW – to the SEC's total available generation capacity in order to bridge the gap between supply and demand during peak load time. So, replacing diesel generators by solar technologies should be considered to mitigate the seasonal peak demand.[93]

One of the main applications of solar energy that Saudi Arabia should pursue is water desalination. For this, scientific research and demonstration projects – being implemented in the Kingdom or abroad with Saudi financial support – need to be coherently articulated with the country's strategies for future RE deployment. According to KACST officials, research, development, and investment in water technologies is a strategic choice for Saudi Arabia due to the lack of traditional water sources, the high costs of their conservation, as well as the high costs of water desalination and treatment.[94] In this sense, energy stakeholders are right

91. Alawaji, "Evaluation of Solar Energy Research and its Applications in Saudi Arabia," 59-77.

92. Twenty-four percent of Saudi Arabia's population is not urbanized, according to 2004 KSA Population Census. See David Satterthwaite *Outside the Large Cities* available at: http://www.iied.org/pubs/display.php?o=10537IIED

93. Saudi Electricity Company, *2020 Ambitious Energy Strategy Report*, 2008.

94. Prince Dr. Turki Bin Saud Bin Mohammed, Vice President of KACST for Research Institutes, addressing the Saudi International Conference for Water Technology 2011 on behalf of KACST's President Dr. Mohammed Bin Ibrahim Al-Suwaiyel; see "Solar Desalination in KSA by 2013,"

to emphasize the importance of research in this area and in related fields. Any technological breakthrough that would reduce the BTUs consumed to desalinate water is considered by ARAMCO officials to be "immensely valuable to (KSA) domestic economy."[95] So, though a first R&D and demonstration plant in Yanbu was closed down for technical and economic reasons, the new R&D activities on solar powered desalination should be sustained to make the new technologies viable, technically and economically, to answer the country's vital and energy-intensive need for potable water.

In the meantime, while RE technological options remain the main focus of expert discussions, the way forward will also depend on how the Saudi social and economic context moves towards more sustainable patterns of energy use.

Saudi Gazette, November 22, 2011, available at http://www.zawya.com/printstory.cfm?storyid=ZAWYA20111122051829&l=051800111122

95. Speech by Khaled al Falih at the MIT Club of Saudi Arabia Dinner; see note 19.

Chapter Six

United Arab Emirates

Electricity: Disparity of Resources

The United Arab Emirates (UAE) is a federation consisting of seven emirates – Abu Dhabi, the capital; Dubai; Sharjah; Ras Al Khaimah; Ajman; Fujairah; and Umm Al Quwain. Each emirate has its own ruler. According to UAE's constitution, oil and gas reserves belong to the local government of each emirate, and federal intervention in decision-making about natural resources is impossible; electricity and water services thus lie under the purview of the emirate in question. For the purposes of this study, the utilities of Abu Dhabi, Dubai, Sharjah and the Northern Emirates will be investigated separately.

Due to fragmentation of the power and water sectors in the UAE and internal imports/exports of these commodities between the emirates, it is difficult to quantify the relationship between hydrocarbon usage and electricity consumption for each of the seven emirates. However, a clear relationship between oil, gas and electricity consumption can be observed on a national level. In 2008, net consumption of electricity hit an all-time high of 70.58 billion KWh. Similarly, petroleum and natural gas consumption reached 3,257 trillion British Thermal Units (BTUs) in 2008, of which 67.5 percent is due to natural gas based electricity generation; this amounted to 2,197 trillion BTUs (equivalent to 2,154 trillion cubic feet), while 1,060 trillion BTUs of petroleum products were consumed for other purposes. [1]

1. According to the US Energy Information Administration, the majority of oil and natural gas re serves are in the emirate of Abu Dhabi, followed by Dubai, with small amounts in Sharjah and Ras Al Khaimah; US Energy Information Administration (EIA) website, *UAE Analysis Brief*, available at http://www.eia.gov/countries/cab.cfm?fips=TC

Abu Dhabi

In the UAE, demand for electricity is the highest in Abu Dhabi, with consumption peaking in August 2009 at 6,255MW, compared with 5,616MW in 2008.[2] The 11.4 percent rise was the biggest annual increase in peak electricity consumption ever recorded in this emirate, where growth in demand averaged 9.1 percent between 2005 and 2010, according to Abu Dhabi Water and E lectricity Company (ADWEC). However, forecasts by ADWEC expect peak power demand in the capital to rise from 6,885MW in 2010 to 11,200MW by 2015 and to 15,500MW by 2020, assuming a forecasted steady average growth rate of 12.5 percent annually. These figures exclude all export by ADWEC to the other emirates.

Indeed, in addition to meeting increased demand in its own emirate, Abu Dhabi also supplies the Northern Emirates with electricity where demand is predicted to climb. At peak times, Abu Dhabi exported up to 1,356MW to the other emirates in the summer of 2009, compared with a maximum of 854MW in 2008. As an emirate with around 10,000MW of installed capacity (in 2009), the increase in Abu Dhabi's electricity demand was easily absorbed by the Abu Dhabi system. However, this may not be the case in the future; if we consider exports by ADWEC to the other emirates, Abu Dhabi's global peak demand should stand at almost 14,000MW by 2015 and 19,400MW by 2020 compared to 8,563MW in 2010.[3]

Together with expansion in the industrial sector demand, this prompted Abu Dhabi to expand its generation capacity with three new power projects – Shuwaihat 2, Shuwaihat 3 and Taweelah C – which have capacities of up to 1,500MW, 1,600MW and 2,400MW, respectively. However, lack of natural gas supplies are threatening to derail the progress of the Taweelah C project.[4]

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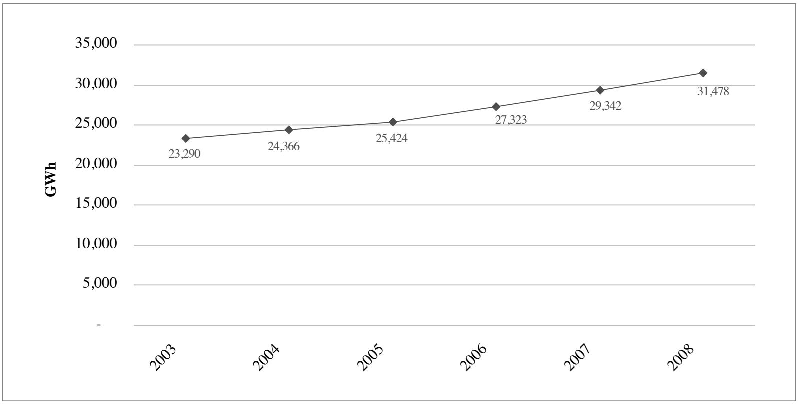
2. Digby Lidstone, "Demand for Electricity Soars in Abu Dhabi," *GCC Power Market Report 2010*, *MEED* supplement, http://www.meed.com/supplements/2010/gcc-power-market-report-2010/demand-for-electricity-soars-in-abu-dhabi/3005256.article

3. For Abu Dhabi Global Peak demand, annual growth rate between 2010 and 2020 is forecast to be 12.65 percent; ADWEC forecasts are available in Keith Miller et al. "ADWEC Winter 2010/2011 Demand Forecast 2011-2030" (Presentation given during MEED Arabian Power and Water Summit 2011, Abu Dhabi, March 2011); Available at: http://www.adwec.ae/Documents/PPT/MEED%20%20March%202011%20-%20110.pdf , also see Lidstone, "Demand for Electricity Soars in Abu Dhabi," *GCC Power Market Report 2010*, *MEED*, http://www.meed.com/supplements/2010/gcc-power-market-report-2010/demand-for-electricity-soars-in-abu-dhabi/3005256.article

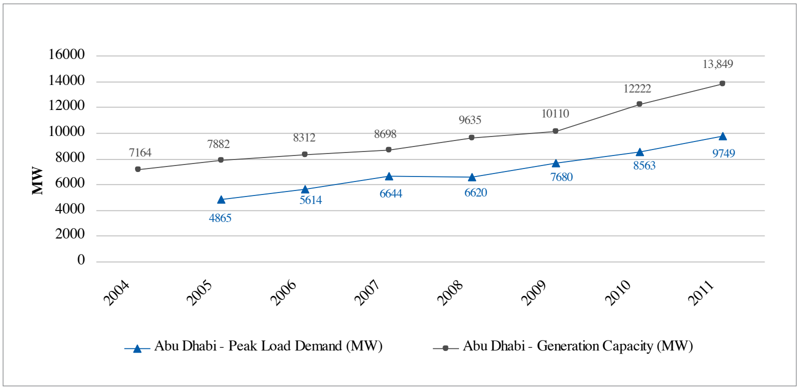
4. As of March 2011, the Shah Gas program which was to supply sour gas to the Taweelah projects is behind schedule and will open after 2013, thereby delaying the study phase of this natural gas project even further. Related articles on http://www.meed.com/sectors/finance/bonds/abu-dhabi-

Growth in Electricity Consumption - Abu Dhabi



This figure excludes energy exports by ADWEC and represents the electricity generation for the emirate of Abu Dhabi only.
Source: Based on ADWEC annual reports

Abu Dhabi - Electricity Capacity and Peak Load 2004 - 2011



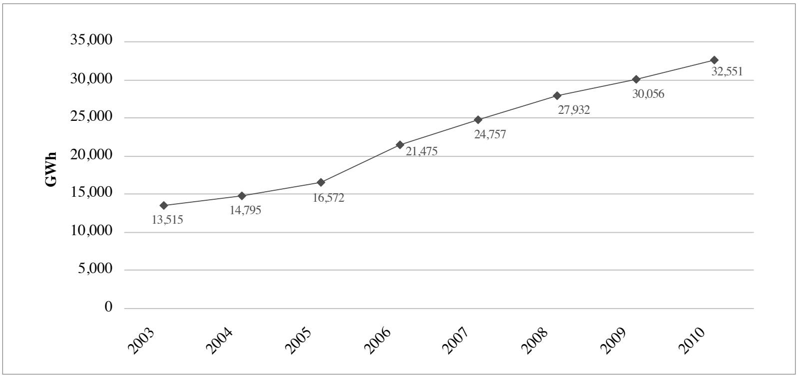
Thanks to a steady increase in its electricity generation capacity, the emirate of Abu Dhabi has been able to meet the increased demand of its population and even to supply some of the northern emirates.
Source: Based on ADWEC annual reports

plans-bond-issue-for-shuweihat-2/3108966.article and http://www.meed.com/sectors/power/shuweihat-s3-reaches-financial-close/3097998.article ; Actually, electricity exports to Dubai and the Northern Emirates, as well as demands by projected industrial projects in the capital could cause the consumption to swell to over 21,000MW in 2015 or 30,000MW by 2020. See Miller et al. "ADWEC Winter 2010/2011 Demand Forecast 2011-2030."

Dubai

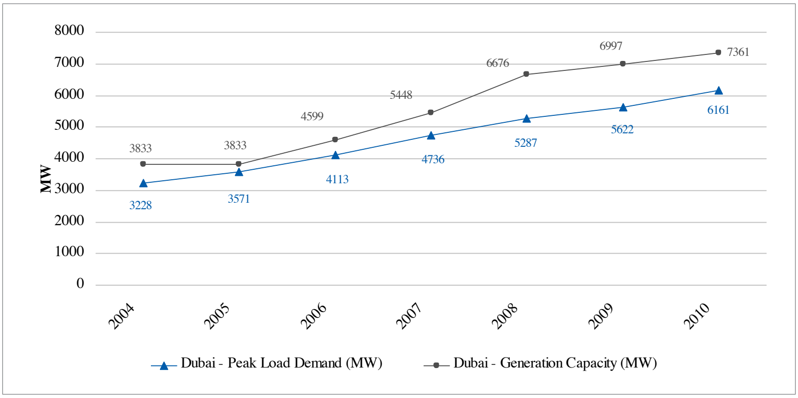
According to Dubai Electricity and Water Authority (DEWA), the electricity capacity of the emirate stood at 7,361MW in 2010, up from 6,997MW in 2009. The capacity was comfortably above the peak demand for electricity in 2010, which was estimated at 6,161 MW.[5] This leaves a reserve of about 16 percent of capacity, which is in line with industry recommendations.

Growth in Electricity Consumption - Dubai



Source: Based on Dubai Electricity and Water Authority (DEWA) statistics

Dubai - Electricity Capacity and Peak Load 2004 - 2010



Dubai's growing needs in electricity have been addressed by parallel growth in generation capacity, which leaves reserves of 15 percent to 20 percent.
Source: Based on Dubai Electricity and Water Authority (DEWA) statistics

5. http://www.dewa.gov.ae/aboutus/electStats2010.aspx

Dubai has seen its year-on-year increase in power demand diminish since the global financial crisis, from around a demand growth rate of 15 percent in 2008 to 8 percent in the following year. As well as highlighting the impact the economic downturn has had on the emirate, this deceleration in the rate of electricity demand growth has also afforded Dubai the chance to pursue its power capacity building plans.[6] Nevertheless, in 2010, the emirate started to import natural gas to meet rising local demand during peak periods. Against this backdrop, it started to draw up its strategy for natural gas requirements until the year 2030.[7]

Dubai also plans to build its first Independent Water and Power Plant (IWPP) that should come online by 2013-2014. The 1,500MW project will be based in Al Hassyan, near Abu Dhabi. It will use natural gas for fuel and is expected to be commissioned in 2014.[8]

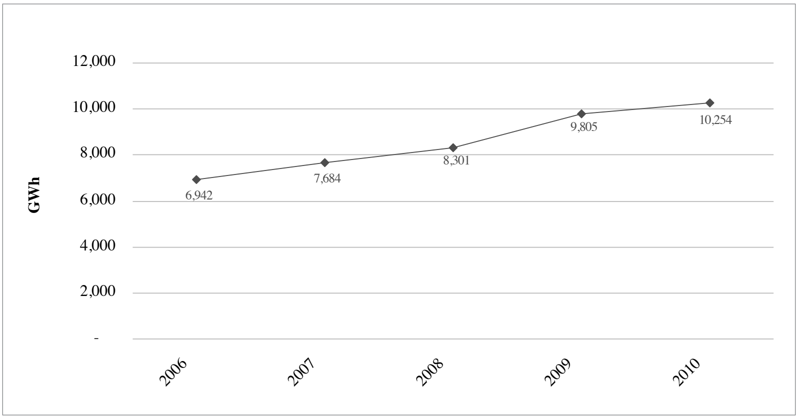
Sharjah

According to the 2008 Oxford Business Group report on Sharjah, the emirate possesses around 1.5 billion barrels of oil reserves, a majority of which is used by the emirate's gas-fired power plants. Sharjah comprises 3.3 percent of landmass of the country, whereas it hosts 40 percent of its total industry hence leading to a considerable demand for energy. An estimate by the local utility provider, Sharjah Electricity & Water Authority (SEWA) predicted the electricity peak demand would reach 4,059MW by 2020, a dramatic rise from 1,565MW in 2007.[9] In the meantime, SEWA power supply increased by roughly 4.4 percent between 2009 and 2010. The utility has 2,576MW of

6. Peak electricity demand was 5,622MW in 2009, compared with 5,287MW in 2008 and 4,736MW in 2007. As per DEWA statistics, Dubai's electricity demands between 2006 and 2008 grew at an astonishing 15 percent per year, decreased to 6percent in 2008-2009 and rose again to 9.5 percent in 2009-2010. See DEWA website for statistics at http://www.dewa.gov.ae/aboutus/electStats2010.aspx
7. In 2010, Dubai started importing 146 Bcf per year of LNG (400.3 Mcf/d) from Qatar to help meet peak electricity demand. The LNG supply agreement is valid for 15 years; more information in US-EIA *UAE Analysis Brief*; see also Oliver Klaus, "Dubai to Award Hassyan IPP Deal in 2Q 2012 - Supreme Energy Council," Dow Jones Newswires, October 4, 2011.
8. Klaus, "Dubai To Award Hassyan IPP Deal" and *MEED* article on http://www.meed.com/sectors/finance/project-finance/dewa-starts-talks-with-lenders-for-first-private-power-scheme/3099110.article
9. Oxford Business Group, *The Report Sharjah 2008*, available at http://www.oxfordbusinessgroup.com/full_content/energy-82

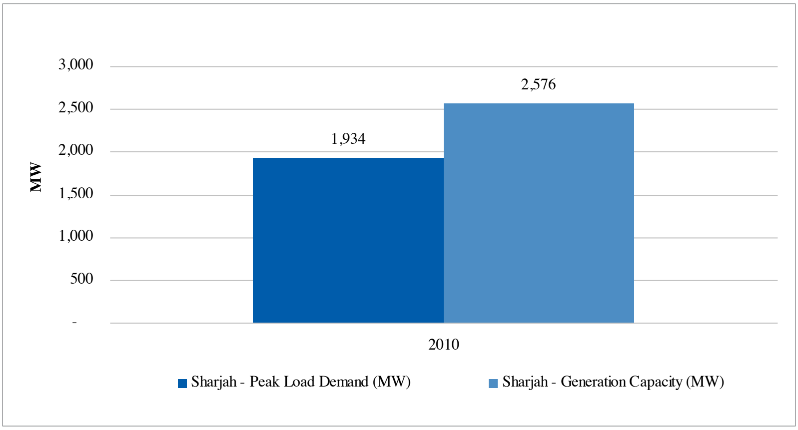
capacity and even though demand peaked in 2010 to 1,934MW, there is still a reserve capacity of 25 percent.[10]

Growth in Electricity Consumption - Sharjah



Source: Based on Sharjah Electricity and Water Authority (SEWA) statistics

Sharjah - Electricity Capacity and Peak Load - 2010



Sharjah has sufficient generating capacity installed (25 percent reserve vs. 2010 peak load), but since the emirate lacks the fuel to operate its power plants, SEWA has had to import an increasing share of its electricity from ADWEA in order to deal with the occasional surges in demand.
Source: Based on Sharjah Electricity and Water Authority (SEWA) statistics

10. SEWA statistics at: http://www.sewa.gov.ae/English/aboutus/stats2011/ELECT-2011-A.pdf

However, while SEWA has sufficient generating capacity installed, it lacks the fuel to run the power plants. The utility receives sufficient gas to meet Sharjah's off-peak demand, but the use of air-conditioning during the hottest months compels it to buy liquid fuels to enable increased power production. This represents a huge financial burden for SEWA, and it is unable to recoup the additional cost through sales to customers because electricity prices in the emirate are subsidized. SEWA also imports electricity from ADWEA to deal with this surge. In 2009, imports from ADWEC totaled 480 MW, a figure that is 70 percent higher than the 2008 figure which stood at 282MW.[11]

The gas supply issue has impacted plans to develop a natural gas-fired facility at Hamriya. The emirate planned to fuel the plant using imported gas from Iran; however, despite the completion of an underwater pipeline in 2006, the National Iranian Oil Company (NIOC) announced in June 2011 that it plans to supply gas to the energy-strapped emirate only by early 2012.[12]

Northern Emirates

The Federal Electricity and Water Authority (FEWA) oversees the provision of utilities for the Northern Emirates. Like SEWA, this utility is dependent on Abu Dhabi for mitigating lack of fuel resources for the Northern Emirates, i.e., Ras Al Khaimah, Ajman, Fujairah and Umm Al Quwain. As of 2009, FEWA has an electricity generation capacity of 1,080MW.[13] Electricity demand in the northern emirates covered by FEWA peaked at 1,840MW in the summer of 2009, 3 percent higher than the maximum consumption of 1,790MW recorded in 2008. Consequently, FEWA had to increase power imports from Abu Dhabi in 2009 to 909MW, a figure that is significantly higher from their 2008 imports which stood at 758MW. Power import is bound to reach 2,500MW by 2015.[14]

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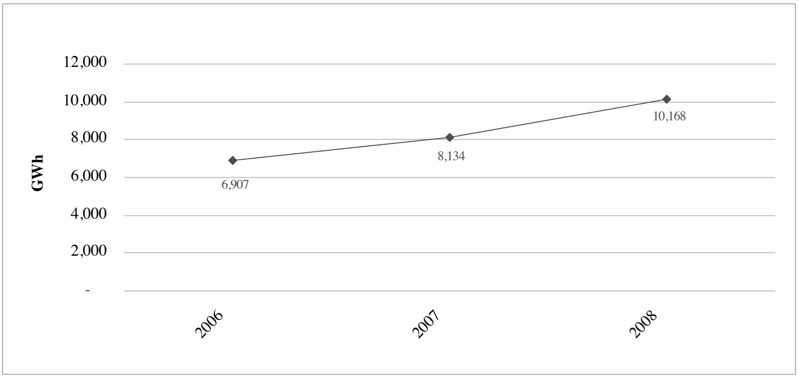
11. For SEWA electricity imports, see Keith Miller et al., "ADWEC Winter 2009/2010 Demand Forecast," 7 (Presentation given during MEED Arabian Power & Water Summit 2010, Abu Dhabi March 2010 available at: http://www.adwec.ae/documents/ppt/2074005133_adwec%20meed%20march%202010%20arabian%20power%20water%20summit%20final%20submitted%20to%20meed.pdf .

12. According to press reports, talks between the National Iranian Oil Company and the Sharjah-based Crescent Petroleum have stalled due to political reasons.

13. FEWA, 2009 statistics. http://www.fewa.gov.ae/_english/fewa/statistics/

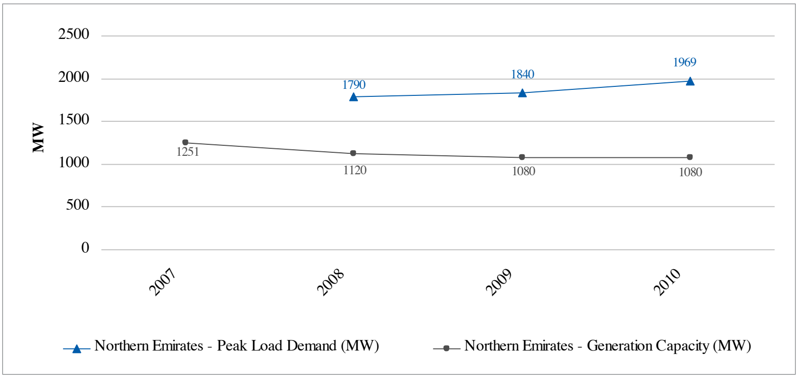
14. Lidstone, "Demand for Electricity Soars in Abu Dhabi", *MEED*, March 28, 2010, http://www.meed.com/supplements/2010/gcc-power-market-report-2010/demand-for-electricity-soars-in-abu-dhabi/3005256.article and for exports figures, see Miller et al., "ADWEC Winter 2009/2010

Growth in Electricity Consumption - Northern Emirates



Source: Based on statistics from UAE's National Bureau of Statistics (2008)

Northern Emirates - Electricity Capacityand Peak Load - 2007 - 2010



Current generation capacity in the four northern emirates is 45 percent below their peak load, which makes the northern emirates vastly dependent on electricity imports from Abu Dhabi.
Source: Based on Federal Electricity and Water Authority (FEWA) statistics

The UAE's federal budget funds both FEWA and ADWEC, and since the Northern Emirates are short on fuel resources, Abu Dhabi provides fuel to FEWA's Fujairah 1 plant that produces around 890MW of electricity.[15] FEWA has recorded a

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Demand Forecast"; Between the years 2007 and 2008, the authority imported a total of nearly 10,000 GWh of electricity as it was unable to cope with the demand especially during the summer months, in FEWA 2009 statistics http://www.fewa.gov.ae/_english/fewa/statistics/

15. Elizabeth Bains, " Fuel Shortage Cuts Electricity Supply in Northern Emirates," *MEED*, Issue No

significant depreciation in generation capacity since 2007. In 2008, FEWA's electricity capacity was 1,120 MW, 10.5 percent less than in 2007 when the capacity was 1,251MW. By 2009, the capacity fell a further 3.5 percent to 1,080MW necessitating an increased reliance on electricity imports from Abu Dhabi's more modern and power plants.[16]

In 2008, the UAE government decided to make FEWA responsible for residential electricity demand only while the individual emirates were to take care of their respective commercial and industrial power needs. This proved to be a challenge. Aside from the Fujairah 1 plant that produces 890 MW, Independent Power Projects (IPP) and Independent Water and Power Projects (IWPP) failed to make it past the planning stage due to lack of fuel for their plants in the Northern Emirates. On the local level, reports suggest that nearly 1,000 residential buildings in the Northern Emirates use diesel-powered generators to mitigate the discomfort of power cuts.[17]

In general, the staggering increase in population and economic expansion in the last decade has caused an increase in the demand for energy in the UAE. As most of the electricity generated in the country uses natural gas as a feedstock, the growing demand has led the country to become a net importer since 2007, when domestic consumption outstripped production for the first time. Growth in peak demand slowed down temporarily between 2008 and 2010; however, domestic needs for natural gas continued to rise while production continued to fall. Indeed, in 2007, the country's electricity generation capacity stood at an approximate 17.7MW but expanded to around 23.2GW in 2010. [18]

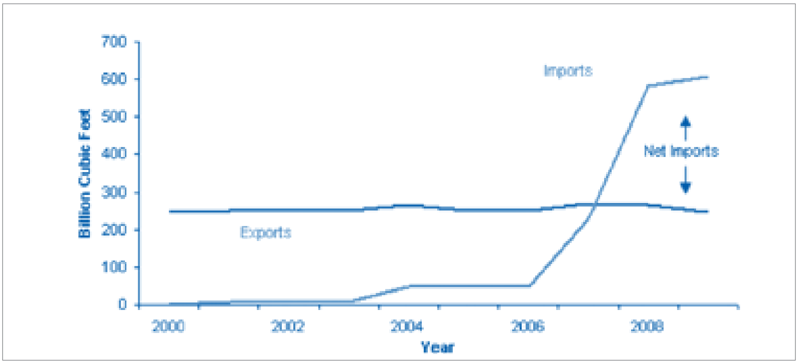
49, December 2009: http://www.meed.com/sectors/power/power-generation/fuel-shortage-cuts-electricity-supply-in-northern-emirates/3002617.article

16. All statistics are available on FEWA's website at http://www.fewa.gov.ae/_english/fewa/statistics/

17. The federal governments of both Ajman and Ras Al Khaimah had decided to build coal powered plants; however, these plans have stalled because of the global recession; Bains, " Fuel Shortage Cuts Electricity Supply" and *MEED Supplement Middle East Power Survey2010, at*: http://www.meed.com/supplements/2010/middle-east-power-survey/feedstock-supply-a-major-concern-for-the-uaes-northern-emirates/3073380.article

18. In 2009, the net deficit in natural gas for all the UAE was 361 billion cubic feet; The UAE possesses 214.4 trillion cubic feet (Tcf) of proven natural gas reserves as of January 1, 2011; The majority of these reserves are located in Abu Dhabi (198.5 Tcf), with marginal amounts found in Sharjah (10.7 Tcf), Dubai (4 Tcf), and Ras Al Khaimah (1.2 Tcf). However, despite UAE's large reserves, production is impeded by big capital costs and high sulfur content. For more information, see US-EIA *UAE Analysis Brief;* Electricity capacity figures are compiled by the author based on ADWEC, DEWA, SEWA and FEWA statistics. The 2010 figure is however

UAE Natural Gas Trade Balance, 2000 - 2009



In 2009, the net deficit in natural gas for all the UAE was 361 billion cubic feet.
Source: EIA's *UAE Analysis Brief*

Despite the economic slowdown caused by the financial crisis of 2008, the UAE demand for electricity has continued to grow in recent years, reaching a level where the national reserves of natural gas are no longer sufficient to meet the country's demand. Since then, the UAE has had to import great quantities of natural gas from neighboring countries, which causes a strain on the balance of trade.

According to the UAE government's white paper on nuclear energy, the peak demand for electricity by 2020 will amount to 40.85GW; however, after 2008, the UAE Ministry of Energy revised its power peak demand forecast from 40GW to 33GW by 2020.[19]

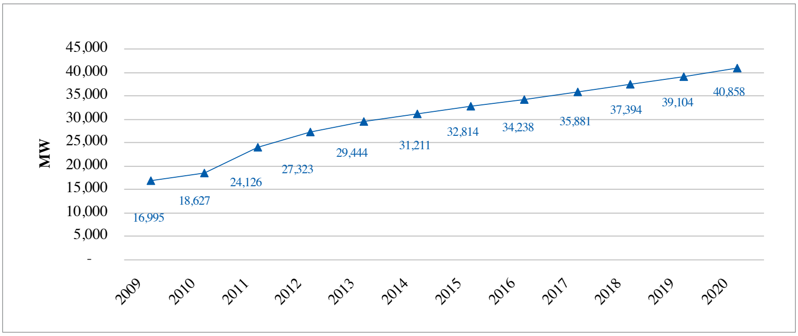
All the same, such growth prospects, coupled with current and future shortages in the country's natural gas supply, prompted the UAE leadership to envisage a diversified energy mix that allows electricity generation from conventional sources - oil and natural gas, renewable energy sources (RES), and nuclear energy. In the last few years, a range of initiatives have been implemented by Abu Dhabi,

different from the estimate given in UAE government White Paper (see graph: UAE Peak Load Demand - Estimates up to 2020)

19. Forecasts are from Federal Authority for Nuclear Regulations, *Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy* (2009), available on http://fanr.gov.ae/ar/media/get/20090430_uae-policy-white-paper.pdf ; UAE's Ministry of Energy have predicted that electricity demand will rise to 33-40GW by 2020; also see Richard Thompson, "The Gulf Looks beyond Gas," March 2010, *MEED*, http://www.meed.com/supplements/2010/gcc-power-market-report-2010/the-gulf-looks-beyond-gas/3005244.article

including commissioning the building of four nuclear reactors, the establishment of the strategic Abu Dhabi-based Future Energy Company (ADFEC Masdar), as well as the introduction of efficiency standards. Behind such preemptive actions is the aim to maintain the country's position in the global energy market while catering for its own growing demand for commodities as vital as electricity and water.[20]

UAE Peak Load Demand (MW) - Estimates up to 2020



After the economic slowdown of 2008, the UAE Ministry of Energy revised its power peak demand forecast for 2020 from 40GW to 33GW. This still represents significant growth in comparison to the 2010 estimate of 18.6GW shown in the graph.
Source: Based on UAE Government White Paper on Nuclear Energy (2008)

Water Scarcity

As of 2011, the UAE's annual demand for water stands at 4.5 billion cubic meters, and is expected to reach 9 billion cubic meters by 2030. Around 51 percent of water is derived from groundwater sources, desalinated water contributes 37 percent and treated sewage water represents 12 percent. Sector-wise consumption of water in the UAE is as follows: 34 percent for irrigation, 32 percent for domestic sector and industry, 15 percent for forestry, 11 percent for landscaping, and a further 8 percent

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20. The UAE's nuclear-power program is a joint venture between state-owned Emirates Nuclear Energy Corp. (ENEC) and Korea Electric Power Corp. (KE); as per latest reports, the plan will cost about $30 billion for the construction of four nuclear plants with a total capacity of 5.6GW, to be completed between 2017 and 2020; Plans for the nuclear power stations on ENEC website: http://www.enec.gov.ae/; reports on latest costs, in Bloomberg, "UAE's Nuclear Power Plan Likely to Cost $30b," November 25, 2011;

for miscellaneous irrigation.[21] It is worth mentioning that water used for agriculture is free of charge while water for municipal use, which is mostly desalinated water, is subsidized by the state.[22]

Rainfall is very low in the UAE; the country has around 150 million cubic meters in renewable water resources, a figure that is very low compared to the country's annual consumption. However, in spite of the harsh weather conditions and soil and water constraints, irrigated agricultural sector expanded, where the total water managed area has trebled from 66,682 ha in 1994 to 226,600 ha in 2003. All irrigation water is groundwater. Local governments especially in the emirates of Abu Dhabi, Dubai and Sharjah are independently responsible for the supply of drinking water and all water affairs in their respective emirates. However, one can see a huge disparity of resources, with more than 86 percent of the farms with modern irrigation systems being located in Abu Dhabi,[23] and 9, 4 and 1 percent in the Central, Northern and Eastern zones, respectively. [24]

Abu Dhabi

In the capital region, Abu Dhabi Water and Electricity Authority (ADWEA) is responsible for the supply and distribution of drinking water whereas the Abu Dhabi Administration of Municipalities and Agriculture (ADAMA) is responsible for the planning, management of groundwater resources, and groundwater recharge. In this context, Abu Dhabi plans to build and replenish aquifers through water desalination plants during periods of excess production in order to have up to 90 days of water available and be able to meet increasing demand during times of water shortage.[25]

21. UAE-wide statistics on electricity and water consumption are difficult to find; these particular figures quote officials from UAE's Ministry of Environment and Water from: Emmanuelle Landais, "Local Water Demand Likely to Double By 2030," *Gulf News*, September 20, 2011: http://gulfnews.com/news/gulf/uae/environment/local-water-demand-likely-to-double-by-2030-1.869877

22. Karen Frenken (ed), *Irrigation in the Middle East Region in Figures—AQUASTAT Survey 2008* (FAO Report 2008), 384.

23. These actually represent over 90 percent of the total irrigated areas of Abu Dhabi; however, only 55, 21 and 75 percent of the total irrigated areas in the Central, Eastern and Northern zones, respectively, of the UAE are covered by such modern irrigation systems ; in Frenken (ed), *Irrigation in the Middle East Region in Figures—AQUASTAT Survey 2008*, 384.

24. Frenken (ed.), *Irrigation in the Middle East Region in Figures—AQUASTAT Survey 2008*, 381-384.

25. ADWEC awarded a $430 million contract to the local/ Lebanese Arabian Construction Company and South Korea's Posco Engineering & Construction to find suitable storage in underground aquifers for the emirate. See Tom Pepper, "Abu Dhabi Builds Strategic Water Reserve," *MEED* Issue 46,November 12-18, 2010 http://www.meed.com/sectors/water/water-supply/abu-dhabi-

In 2005, the total water consumption in Abu Dhabi amounted to 3,998 million cubic meters a year; of this, 83 percent was used for irrigation, 15 percent was withdrawn for municipal needs, and industries used the remaining 2 percent. In the same year, over 70 percent of water in Abu Dhabi was obtained from groundwater, 24 percent was obtained through desalination, and 6 percent was reused wastewater. Hence, the volume of desalinated water consumed in Abu Dhabi in 2005 was about 578.25 million imperial gallon a day (MIGD).[26]

According to ADWEC, in 2010, Abu Dhabi was responsible for producing 672 MIGD of desalinated water; which – compared to 2005 FAO estimates – represents an increase of almost 16.5 percent, or an average growth rate of 3.3 percent per year between 2005 and 2010. ADWEC, however, expects desalinated water demand to grow by an average of 5.3 percent annually, reaching 850 MIGD by 2015 and 1028 MIGD by 2020, including exports.[27]

According to ADWEA and FEWA, desalinated water met 75 percent of potable water demand in Abu Dhabi emirate in 2000, whereas in 2010 it covered 95 percent of this demand.[28]

Dubai

Like Abu Dhabi, around 95 percent of Dubai's potable water is obtained through desalination, while the remaining 5 percent is acquired from wells. Dubai's potable water production capacity was steady at 300MIGD for both 2009 and 2010; the residential sector accounted for 60 percent of the consumption while the remaining was distributed among the commercial, industrial and governmental sectors.[29]

As per 2008 projections, Dubai's water storage capacity should reach 415 MIGD. However, this capacity will account for less than half of Dubai's estimated daily water demand by 2015.[30] Water demand in Dubai increased at an estimated

builds-strategic-water-reserve/3078278.article

26. 1 cubic meter = 219.96924 imperial (UK) gallon; Water statistics for 2005 from *Irrigation in* Frenken (ed), *Irrigation in the Middle East Region in Figures—AQUASTAT Survey 2008*, 380. However the figure for desalinated water from FAO report is different from ADWEC's figure for the same (402 vs. 578 MIGD).

27. http://www.adwec.ae/Documents/PPT/MEED%20%20March%202011%20-%20110.pdf

28. Al-Hosani et al., "Water Demand Forecast and Management of United Arab Emirates 2000-2010", ADWEA and FEWA Directions of Projects," (2011) and Pepper, "Abu Dhabi Builds Strategic Water Reserve."

29. DEWA Water Statistics in: http://www.dewa.gov.ae/aboutus/waterStats2010.aspx

30. In 2008, DEWA awarded a $168.6 million contract to the local Mammut Group (in conjunction

average annual growth rate of 15 percent till 2008, but the rate dropped to 9.5 percent per year between 2009 and 2010.[31]

Sharjah

Sharjah's potable water production decreased from 32,591 MIGD to 31,941 MIGD, representing a decrease in capacity of 1.9 percent between 2009 and 2010. Unlike ADWEA or DEWA, SEWA obtains around 20 percent of its potable water from underground sources, and the rest from desalination plants. In 2010, the residential sector was the highest water consumer (62.2 percent), followed by the commercial sector (26.1 percent), government sector (11.4 percent) and other miscellaneous sectors (1.9 percent).[32] Sharjah has had problems in water supply in the recent past; two desalination units were delayed by SEWA as a result of the 2008-2009 economic crisis. [33]

Northern Emirates

FEWA has an installed water capacity of 46.5 MIGD, from both Multi Effect Distillation and Reverse Osmosis plants. Although this figure remained unchanged between the years 2008 and 2009, FEWA water production increased by 6.7 percent during this period to reach an average of 34.6 MIGD.[34] In 2010, of the 672 MIGD of water produced in Abu Dhabi facilities, 649 MIGD were used within the emirate, while 23 MIGD were exported to the Northern Emirates. Forecasts by ADWEC project these exports to reach 42 MIGD by 2015 and 61 MIGD by 2020, an increase of 165 percent compared to the amount exported in 2010.[35]

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with Germany's Maz Boegel Group) to build a massive water reservoir in Mushrif, in http://gulfnews.com/business/construction/dubai-builds-world-s-largest-water-reservoirs-1.92775

31. Growth rates calculated from DEWA statistics.

32. Statistics and percentages are obtained or based on water reports by SEWA, http://www.sewa.gov.ae/English/aboutus/stats2011/WATER-2011-A.pdf and http://www.sewa.gov.ae/English/aboutus/stats2011/WATER-2011-B.pdf. In terms of water security, SEWA employs the same strategy as DEWA by storing its water reserves in reservoir tanks. Latest figures point to the fact that SEWA has the potential to store just over two days worth of water supplies in ground level and elevated tanks.

33. Karin Maree, "Sharjah Shelves Hamriya Power and Water Projects," *MEED*, January 19, 2009:http://www.meed.com/sectors/power/sharjah-shelves-hamriya-power-and-water-projects/1968419.article

34. Author's calculations based on statistics obtained from FEWA reports at: http://www.fewa.gov.ae/_english/fewa/statistics/

35. Miller et al. "ADWEC Winter 2010/2011 Demand Forecast 2011-2030";

Water is an essential resource that is at risk in the UAE. Rainfall is poor, and groundwater reserves and desalinated water are the only possible source of freshwater for the country's growing population.

The UAE National Environmental Action Plan for Water Resources which is in charge of the National Environmental Strategy for Water Resources implemented some guidelines to address supply and demand management issues in all emirates. The measures include:

- An increase in water resources through enhanced aquifer recharge [mainly through water desalination] and potential use of alternative methods such as treated municipal wastewater;
- Sustainable desalination as the principal supply source for municipal water demands; and
- Possible use of solar power for the desalination of brackish groundwater for rural areas.[36]

Considering the big increase in total water demand in the UAE, the irrigation expansion in spite of the country's arid climate, and the rapidly depleting groundwater resources,[37] one can easily realize how water production and food security are critical points in the UAE government's agenda. All these factors will undoubtedly lead to a growing share of desalinated water in the country's overall consumption of this precious commodity. However, as desalination is an energy-intensive process, such a trend will exacerbate the energy needs of the country and put more pressure on its environment.

CO_2 Emissions and Energy Intensity

In the UAE, per capita CO_2 emissions grew from 26.435 tons/pop in 2005 to 32.186 in 2008, hence reaching a growth rate of 7 percent annually. In the year following the economic slowdown, per capita emissions decreased by one percent, to 31.972 tons/pop in 2009. These figures are among the highest globally, second only to another GCC country, Qatar. In view of the economic and energy forecasts, emissions are poised to increase even more.

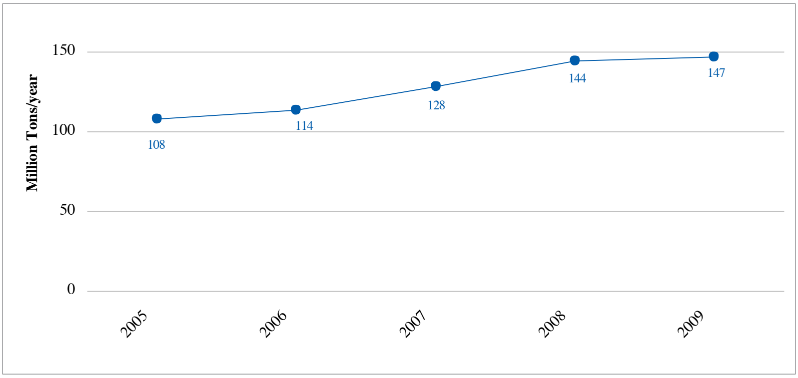
Indeed, although the UAE remains largely dependent upon the hydrocarbons

36. Ibid, 385.

37. According to FAO Reports, "over-extraction of groundwater resources is real and has to do with the lowering of the watertable in the UAE," in Frenken (ed.), *Irrigation in the Middle East Region in Figures—AQUASTAT Survey 2008*, 380 and 385.

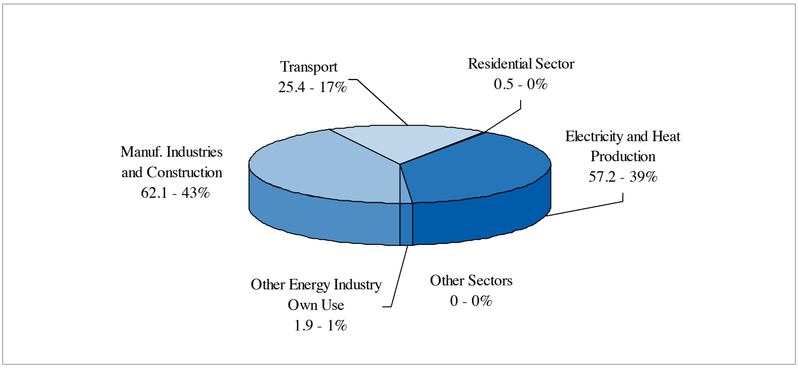
sector for economic growth, economic transformations have taken place and continue to step-change the level of industrialization of the country (Ports, Free Zones, Industrial zones, etc.). At a national level, total CO_2 emissions were rising at an annual growth rate of 9 percent, between 2005 and 2009; they registered 147 million tons in 2009, 39 percent of which was due to the electricity and heat production sector.

UAE CO_2 Emissions 2005 - 2009



Source: Based on IEA, *CO_2 Highlights* (2011)

UAE CO_2 Emissions from Fuel Combustion in 2009 by Sector (million tons)



The needs in energy of its growing population and industries have made of the UAE the second largest country in per-capita CO_2 emissions in the world. However, in 2009 UAE saw a most-welcome decline in per-capita emissions.
Source: Based on IEA, *CO_2 Highlights* (2011)

Nevertheless, it is important to note that, in parallel to the growth of the total and per capita emissions in the UAE between 2005 and 2008, energy intensity has also grown at 1 percent annually; hence increasing energy demand in the country has not only resulted in growing pollution, but has also been accompanied by less efficient use of energy. [38]

Potential of Renewable Energy Sources (RES): Studies and R&D

The UAE climate is arid, hot and humid in the summer with very high summer temperatures and relative humidity reaching 46°C and 100 percent, respectively. However, due to its geographical position – between latitudes 40° North and 40° South, or what is called 'the solar belt' – the country is blessed with an abundance of solar energy.

Studies confirm that solar potential is high in the UAE. For the harnessing of energy from photovoltaic (PV) cells, the annual Global Horizontal Irradiance (GHI) for the UAE stands at 2.12 MWh/m^2/y, the highest potential in any member country of the GCC. The country also has a relatively high potential for Direct Normal Irradiance (DNI), which at 2.2 MWh/m^2/y is considered to be suitable for Concentrated Solar Power (CSP) technology.[39]

Photovoltaic Energy

According to many studies, the use of PV cells in the UAE represents one of the most promising and reliable renewable energy technologies. In order to study the suitability of the UAE climate to the implementation of this technology, the Petroleum Institute in Abu Dhabi conducted a study to analyze the GHI in multiple locations of the emirate from 2007 to 2009. Hourly, daily, monthly GHI values were computed and statistically evaluated. The highest values of monthly GHI ranged from 657 W/m^2 in January to 929 W/m^2 in June; May, June and July contributed the most to the annual GHI, while November, December and January had the lowest values. However, it is worth mentioning that between July and

38. CO_2 emission figures are from International Energy Agency (IEA), IEA CO_2 Highlights 2011; Energy intensity growth rate is based on International Energy Agency, *IEA Key World Energy Statistics, 2005 – 2010*.

39. German Aerospace Center (DLR), *Concentrating Solar Power for the Mediterranean Region* (2005), Institute of Technical Thermodynamics, Section Systems and Technology Assessment, 57.

September, Abu Dhabi – like the rest of the UAE – sees a dip in GHI due to its characteristic high temperature and humidity. At the same time, results have also shown a high percentage – 82 percent – of clear days during the year and that the annual average number of hours per day of suitable GHI – that is above 500 W/ m^2 – was six hours a day, which confirms that PV application in Abu Dhabi is technically viable.[40]

Nevertheless, an assessment of the technical and economic viability of some PV systems and their connection to the grid in the Abu Dhabi region yielded mitigated results. For instance, a study by the Petroleum Institute has focused on the environmental effects impacting a specific PV technology, i.e. thin-film, amorphous silicon (a-Si) photovoltaic system, in terms of its intrinsic power output or its connectivity to the grid. While these types of cells have lower electricity production costs, their efficiency ranges between 6 and 8 percent only. The authors observed that the average efficiency of the system being investigated in the study did not exceed 4.82 percent and that, apart from the 30 percent drop in efficiency inherent to the a-Si technology (Staebler Wronski effect), further decrease happened mainly due to dust accumulation rather than humidity and/or increasing temperatures. Furthermore, a significant loss in power occurred as the latter was fed into the grid through the inverter, thus degrading the performance of the system by 11.82 percent from 4.82 to 4.24 percent.[41]

On the other hand, environmental and health benefits of PV technologies were found to justify governmental funding for such clean energy projects. A study was conducted by the University of North Carolina, Chapel Hill to examine the feasibility, costs and benefits associated with such projects. The analysis was carried out to forecast energy production, financial feasibility, and anticipated reductions in Greenhouse Gases (GHG) emissions in a PV-powered 10MW grid-connected PV

40. L. El Char and L. Lamont, "Global Solar Radiation: Multiple on-site Assessments in Abu Dhabi, UAE," *Renewable Energy* 35 (2010): 1596- 1601. In a different study, averages of solar irradiance on horizontal and tilted planes in different directions were calculated and the global irradiance on a horizontal surface (GHI) in Al Ain, Abu Dhabi and Dubai was estimated at 1975, 1950 and 1930 KWh/m^2/y, respectively. Further, to maximize solar power production from a south-facing surface in the UAE, the optimal tilt angle was found to be 24 (site latitude). See H. Radhi, "Energy Analysis of Façade-integrated Photovoltaic Systems Applied to UAE Commercial Buildings," *Solar Energy* 84 (2010): 2009-2021; 2010.

41. T. Al Hanai, R. Bani Hashim, L. El Chaar, L.A. Lamont, "Environmental Effects on a Grid Connected 900W Photovoltaic Thin-film Amorphous Silicon System," *Renewable Energy* 36 (2011): 2615-2622.

plant.[42] It assumes that the effect of the Abu Dhabi climate – mainly the dust – on PV cells will decrease annual production by 5 percent, thus limiting the production of the proposed plant to 24.4GWh, while its peak production will still coincide with peak monthly demand.[43]

So, taking into account the initial costs and the exported electricity rate (that is, the price paid by ADWEA/ADWEC to export electricity from the nearest plant to the local power grid, which is estimated at $0.082/kWh), and assuming that the PV project does not receive GHG emissions credits, the study finds that investment in solar energy is financially not profitable as total initial costs would be around $92 million (NPV negative) with a 30-year time lag to positive cash flow.

The Net Present Value (NPV) roughly depends on the initial costs, and the income of the project was found to be negative (-$51million) demonstrating that solar power costs are still too high. However, if the PV electricity export rate was raised to $0.16/kwh or higher (instead of $0.082/kWh), or the total initial costs were to go below $41million, the NPV for the project would be positive. However, the study concludes that if environmental damage costs and social benefits of reduced air pollution – estimated to have a present value of approximately $47.4 million – were taken into account, findings would justify support to PV projects and confirm that government incentives are needed to make these projects profitable.[44]

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42. For purposes of technical and economic modeling of the proposed plan, the study uses the RETscreen modeling software and considers the performance of mono-silicon BP Solar 90W modules (mounted on one-axis tracking system), the monthly averages of mean GHI registered for Abu Dhabi's national Airport, and the capacity and annual emissions data compiled for a gas-fired power plant located in Um Al Nar/Abu Dhabi; E. Harder and J. Gibson MacDonald, "The Costs and Benefits of Large scale Photovoltaic Power Production in Abu Dhabi, United Arab Emirates," *Renewable Energy* 36 (2011): 789-796.

43. GHI figures are NASA's 22-year monthly averages of mean GHI for Abu Dhabi Airport as it is the closest location to Um Al Nar power plant; following the per capita power consumption figures of the UAE for 2008, 24.4GWh could meet the needs of 1975 people. Ibid., 791 and 793.

44. Ibid., 793-796. The current UAE export cost: As of 2008, export charges are $0.0081-0.0135/kwh for its UAE nationals, $0.0405 for expatriates and industrial customers. These figures are the lowest charges for electricity by any utility provider in the country. ADWEC electricity tariffs can be found at- http://www.rsb.gov.ae/uploads/InfoElecTariffsLargeUsersNov09.pdf ; If ADWEA were to increase the electricity tariffs, it could further bring down the price tag of the $50 million 10mw photovoltaic plant. See http://www.meed.com/abu-dhabi-taking-the-lead-on-clean-energy/3104158.article

Concentrating Solar Power (CSP)

As generally argued, Concentrating Solar Power technologies (CSP) have relative advantages over PV panels, when we consider the major inconvenience of solar energy intermittency. Indeed, storage of solar power becomes as important as its generation since the sun is not available at all times. However, in solar thermal technologies, solar heat collected during daylight hours can be stored in concrete, molten salts or ceramics and can be harnessed for steam turbines to generate electricity at night when solar energy is not available. In other words, molten salt is considered an effective storage system for solar thermal technology like CSP that has a low cost.[45]

In 2010, a joint study carried out in Abu Dhabi by the Petroleum Institute and the University of Maryland measured direct beam radiation (equivalent to Direct Normal Irradiance or DNI) - the assessment of which is useful to determine the potential of Concentrated Solar Power (CSP) systems. After recording the climactic conditions, temperature, wind speed, humidity and clearness index for the year 2007, the study found the average DNI was 400W/m^2 throughout the year which confirms that CSP could be used effectively in Abu Dhabi. Monthly averages of the mean DNI were found to be higher for the periods between March-May and September-November and show that recorded values are specifically highest in the months of April and May whereas those recorded in July and August are the lowest. [46]

More generally, an assessment of the UAE solar potential indicates, according to a German Aerospace Center (DLR) study, high values of both technical and economic potentials for CSP electricity, putting the first at 2,078 TWh/y and the second at 1,988 TWh/y, respectively. However, as emphasized by DLR, these assessments are conducted in isolated conditions and do not account for unique atmospheric and weather patterns. For the development of large-scale CSP projects, at least 5 to 15 years of DNI data must be processed and a one-year data basis is not considered to be enough, as the annual climatic fluctuations can be in the range of + or - 15 percent.[47] It is interesting to note here that the developers of the CSP-based Shams 1 project (discussed later in the chapter) which will generate about

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45. German Aerospace Center (DLR), *Concentrating Solar Power*, 42.
46. M.D. Islam, A.A. Alili, I. Kubo, and M. Ohadi, "Measurement of Solar Energy (direct beam radiation) in Abu Dhabi, UAE," *Renewable Energy* 35 (2010): 515-519.
47. For the definition of the technical and economic potential, refer to note 24 in Bahrain chapter. The Direct Normal Irradiance (DNI) for the UAE was estimated at 2,200 KW/m^2/y. See German Aerospace Center (DLR), *Concentrating Solar Power*, 56-57.

100MW with 768 parabolic mirrors have already experienced some setbacks as dust particles in the region have decreased the amount of irradiation that should be captured by the mirrors. The developers have had to order more of these to combat the phenomena and achieve the targeted capacity [48]

Nevertheless, research on CSP technologies is progressing in Abu Dhabi. In the context of the research program called 'Beam-Down Solar Tower' and involving Masdar Institute of Science and Technology (MIST), Japan's Cosmo Oil, and the Tokyo Institute of Science and Technology, exploration of a new design for a Solar Tower is taking place, with testing and measuring of its efficiency under local weather conditions. A pilot plant of 100KW capacity was built next to Masdar city and has been monitored since a few years by MIST researchers. In general, solar tower technologies use an array of ground disposed mirrors to direct sun rays onto a receiver or heat exchanger placed at the top of a central tower; the exchanger converts the solar energy into hot compressed air, which is used to drive turbines at ground level. The beam-down solar tower design inverts this process by placing the heat exchanger at the bottom of the tower, hence reducing the costs of pumping liquids up the tower's length. Central mirrors on top of the tower re-direct sun rays onto the heat exchanger placed at the bottom. This also means lower costs for the engineering and equipment needed for the other ground mirrors to track the sun throughout the day.[49]

This new design is also thought to maximize efficiency of the solar tower technology. However, based on monitoring of the pilot plant, it was reported that, while reducing costs, the beam-down tower technology reduced efficiency from over 20 percent to 15-19 percent.[50] Hence, it will need more R&D effort before such technology matures and is eventually deployed in commercial-scale power plants.

The UAE's efforts to search and find new RE solutions to its increasingly energy-savvy industrialization are also evident in the joint R&D projects championed by the Government of Ras Al Khaimah and the Swiss research center "Centre Suisse

48. Despite the unexpected demand of materials for the plant, officials at Masdar have claimed that the initial $600 million price tag for Shams 1 will remain the same: http://www.bloomberg.com/news/2010-10-27/dust-blocking-sun-s-rays-at-solar-plant-in-uae-masdar-official-says.html

49. Press release "Masdar, Tokyo Institute of Technology, Cosmo Oil Partner to Develop Solar Thermal 'Beam Down' Technology," December 17, 2007 in http://www.masdarcity.ae/en/75/resource-centre/press-releases/?view=details&id=52; Comments on the viability of the beam-down technology by Tariq Ali, the vice president for research at the Masdar Institute in Chris Stanton, "Masdar's New Slant on Solar Energy," *The National,* January 14, 2010 at: http://www.thenational.ae/business/energy/masdars-new-slant-on-solar-energy

50. http://www.greenoptimistic.com/2010/01/22/masdar-beam-down-solar-concentrator

d'Electronique et de Microtechnique" (CSEM). CSEM-UAE was founded in 2005 and focused its attention on addressing local needs such as looming shortage of electric energy.[51] Against this backdrop, the center proposed and designed a solar-island prototype and sought to evaluate its technical feasibility and cost effectiveness in generating electricity. This prototype consists of a 5000 m² platform, measuring 100 meters in diameter and stretching across a circular floating pontoon to ensure tracking of the sun; solar mirrors mounted on this platform would reflect sunrays onto water filled pipes to create steam and drive turbines. Construction of the platform was achieved in 2008 and its floating test – over a water-filled channel sustaining the outer ring (pontoon) of the prototype – was performed in 2009. In 2010, the precision tracking test was reported to be successfully performed too, confirming that the solar-island prototype can track the sun to within 0.02 degrees of precision. All these positive results need to be furthered by R&D on the structures of the solar collectors as well as efficient thermal-electrical conversion system. Nevertheless, CSEM-UAE confirms that this pilot can produce up to 1MW of thermal energy, with average power of 250KW and annual energy production reaching 2.2GWh. The total investment in the project has reached $5 million.

Since 2009, RAK-based CSEM-UAE has focused on immediate energy solutions and shorter-term energy-efficiency projects (Waste Heat research) and their evaluation with carbon credit. Another focus is solar cooling, where CSEM-UAE started building, in 2010, the Solar Cool Research Center and solar facilities to develop Solar Insulation Material and solar-assisted air conditioning. In early 2011, CSEM-UAE successfully tested the solar cooling center with 1 ton of refrigeration and decided on its extension to 10 tons of refrigeration. All such activities take place at the solar R&D facilities established in 2007 on about 87,000 sq.m of land in Al Jazeera Al Hamrah area. Cooperation with international academic, technology and industrial development centers is encouraged. Collaborating institutions include the Royal Institute of Technology in Sweden, the Swiss Federal Institute of Technology in Lausanne-Switzerland and in the Middle East at Ras Al Khaimah (EPFL and EPFL-ME) and Heriott-Watt University in UK, Dubai campus.[52]

51. In 2009, a report by Oxford Business Group cited power shortages as the biggest bottleneck to the Ras Al Khaimah industrial sector, which uses 35 to 55 per cent of the emirate's power supply, in Anna Zacharia, "RAK's Solar Islands Could Power Emirate," *The National*, September 13, 2010, available at http://www.thenational.ae/news/uae-news/raks-solar-islands-could-power-emirate . More information on CSEM-UAE can be found on their website: http://www.csem-uae.com/profile5.php.

52. Since its inauguration, solar radiation measurement and weather stations have been installed in

Wind Energy in Fujairah and Bani Yas Island

Based on 2002 data, rough estimates prepared by the German DLR indicated that onshore average wind speed does not exceed 5.0 m/s but can reach 7.5 m/s on the shore line. Furthermore, the country has only 1,176 of full load hours per year at 80 meters height – this figure corresponds to a capacity factor (performance indicator) that is too low to ensure an economically viable wind energy plant. The technical and economic potentials for wind power generation were hence not determined in this study.[53]

As per this performance indicator, the construction of wind farms in the UAE would not be a prudent investment. However, data collection confirmed that in some parts of the UAE, average wind speed is more than 6m/s, which is very suitable for small-scale power generation or pumping water for irrigation.

A study by the American University of Sharjah and the Ontario Institute of Technology focused on the emirate of Sharjah, its local atmospheric conditions and wind characteristics. The study found that the highest wind speeds occurred during January (8.2m/s), February (9.8m/s) and March (12 m/s). Nevertheless, the ideal performance of the turbine used in their simulation[54] was obtained at a wind speed of about 11.25 m/s; given the moderate wind speed in Sharjah, it was recommended that turbines with low cut-in speed be used to make as much use as possible of the available wind power.[55] Wind speed data were also collected for Abu Dhabi in a study conducted during 2007 by the Petroleum

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the CSEM-UAE solar facilities in Al Jazeera Al Hamrah area. All information on RAK's Solar Islands on CSEM-UAE website at http://www.csem-uae.com/profile5.php; some statements are by Dr Hamid Kayal, CEO of CSEM-UAE in Anna Zakaria, "RAK's Solar Islands Could Power Emirate." See also Asian Solar, "Solar Islands: Can RAK's Vision Provide a Gulf-wide Solution," January 2010, available at http://www.asiansolarmag.com

53. Areas with annual full load hours over 1,400h/y equivalent to a capcity factor of 16 percent are considered in this study as long-term economic potential; in German Aerospace Center (DLR), *Concentrating Solar Power,* Table 3-2, pp. 57 and 68.

54. The study measured the thermodynamic performance of a medium-wind turbine of 850KW from Vestas – with a cut-in and cut-out speed of 4 and 25 m/s, respectively, and found that the power generated during January, February and March was 8,732KWh, 21,108KWh, and 25,473 and 25,473 KWh, respectively. A.M Redha, I. Dincer, and M.Gadalla, "Thermodynamic Performance Assessment of Wind Energy systems: An Application," *Energy* 36 (2011): 4002-4010.

55. Ibid. Considering that Sewa's monthly power generation for March is around 630 million kWh, such wind turbines should be deployed in the hundreds in order to reduce the stress of electricity demand in Sharjah. Statistics from http://www.sewa.gov.ae/English/aboutus/stats2011/ELECT-2011-A.pdf , 6.

Institute. The study showed that higher winds occur in the April-October period, when average wind speed varies between a maximum of 13km/h and minimum of 7km/h.[56]

Wind energy conversion systems were also investigated in some theoretical or demonstration studies. For instance, Spanish-based wind energy company Energia Hidroelectrica de Navarra ((EHN) investigated the economic feasibility of building four wind farms for generating electricity in the emirate of Fujairah. Following data collection and analysis over an 18-month period by EHN engineers in collaboration with the Fujairah Department of Industry and Economics and the UAE University, wind farms with power generation capacity ranging between 130 and 200 MW per year were "expected to be erected near Dhadnah, Masafi, and Fujairah city in Fujairah."[57]

Deployment of wind energy conversion systems also took place in the UAE, with Sir Bani Yas Island, located 250 km southwest of Abu Dhabi, displaying a large 850 KW Vestas wind turbine.[58] Germany's Dornier Consulting and GTZ undertook the project and were in charge of operating the plant for two years (2005-2006). After this operation and monitoring exercise, it was observed that wind speed in the island averages 5.1 m/s and that the number of full load hours ranges between 1,200 to 1,300, which correspond to a capacity factor of 13.7 -14.8 percent. The whole system yielded an annual energy of 1,000 MWh, at an electricity cost (COE) of Euro0.10/KWh; this amounted approximately to US cent12.7/KWh, using the mean exchange rate of 1.27 for the years 2005-2006.[59]

Connected to the island's grid, the Sir Bani Yas wind system is seen as a trendsetter for sustainable development in the UAE's electricity sector. Indeed, following this first experience, Masdar Power is considering the building of an

56. Islam, Alili, Kubo, and Ohadi, "Measurement of Solar-Energy (direct beam radiation) in Abu Dhabi, UAE."

57. A. Kazim, "Strategy for Sustainable Development in the UAE through Hydrogen Energy," *Renewable Energy* 35 (2010): 2257-2269, specially 2260.

58. The Bani Yas turbine is the same VESTAS turbine considered in the simulation study conducted for Sharjah and described earlier. For more information, see Redha, Dincer, and Gadalla, "Thermodynamic Performance Assessment of Wind Energy Systems," 4002; also see Kazim, "Strategy for Sustainable Development in the UAE," 2260.

59. PowerPoint Presentation by Joachim Kaufler (Synlift Systems GmbH - Berlin), "Umwelt-dienstleistungen: Win-Win Potenziiale und Exportchancen fur deutsche Unternehmen-Experience in Morocco and Abu-Dhabi (UEA)" [Environmental services: Win-Win potential and Export Opportunities for German Companies - Experience in Morocco and Abu-Dhabi (UEA)], November 22 and 23, 2007, Berlin, Germany.

onshore 30MW wind farm on the same island, which on completion would be connected to the Abu Dhabi grid.[60]

Hydrogen Energy

Some studies have also been conducted in the UAE to assess the potential of hydrogen energy as an energy carrier that can be used in fuel cells to generate electric power. Besides the fact that hydrogen is storable and transportable, it is considered to be environmentally clean and inexhaustible especially when produced through renewable energy sources. The feasibility of implementing a solar to hydrogen energy system for the UAE was investigated in a study in 2001; in the technical and economic analysis, the author took into consideration population growth, energy demand and production, income from sales of fossil fuels, and PV cell area required for installing such a system in order to determine the potential production and income from sales of solar hydrogen till 2100. According to the study's predictions, an area of 1,000 km^2 using PV cells of 18 percent of efficiency will be required to produce 10^9 Giga joules per year of hydrogen by 2020, which should account for 20 percent of the total energy income of \$80x10^9 of the UAE.[61]

In fact, the potential of conventional and non-conventional energy resources that could contribute significantly to the production of hydrogen in the UAE have been investigated for the last 10 years. A review of these studies leads to the conclusion that, notwithstanding the low operating efficiency and high CO_2 emissions of the natural gas steam reformation process, the cost of hydrogen produced by such process – at 10 percent of utilization rate of the UAE's present production of natural gas – proves to be more favorable than hydrogen produced from renewable resources; the cost of the former is \$8.2/ Giga joule, which is found to be 10 percent, 45 percent, and 57 percent less than biomass hydrogen, solar-hydrogen, and wind-hydrogen systems, respectively. However, as the cost of natural gas will increase as a result of its massive utilization and its imminent scarcity in the near future, the cost of hydrogen

60. The announcement was made in the middle of 2011; however, at the time of writing no major progress has been done on the request for proposals; for information on the 30 MW wind power plant, see Masdar's press release May, 2011: http://www.masdar.ae/en/MediaArticle/Newsription.aspx?News_ID=198&News_Type=PR&MenuID=0&CatID=64

61. A. Kazim, T.N. Veziroglu, "Utilization of Solar-Hydrogen Energy in the UAE to Maintain its Share in the World Energy Market for the 21st Century," *Renewable Energy* 24 (2001): 259-274. One watt is one Joule per second, so a KWh is 3,600,000 Joules

produced by gas will increase by 70 percent in the long term.[62]

However, the sustainability of the biomass-hydrogen option in the UAE will depend on the sustainability of the country's agricultural sector and its increasing consumption of scarce water. Similarly, wind potential is low, leaving the solar to hydrogen option as the most technically viable among all in the UAE context.

Biofuels

With such sustainability constraints in mind, an integrated seawater agriculture system for the production of aviation biofuels has been the subject of studies led by the Sustainable Bio-energy Research Center (SBRC) to assess its technical, economic and environmental viability. Through a five-year Industry-University linkage program involving Masdar Institute of Science and Technology, Etihad Airlines, Boeing and Honeywell's UOP, SBRC researchers are conducting agronomic studies on *Salicornia-bigelovii* cultivation in the arid land of the UAE using seawater irrigation. Their assessment studies address the sustainability of the yields and the uses of *Salicornia* (e.g., for biomass electricity generation, fish feed in aquaculture, etc.), the agronomic risks as well as the land availability to develop a low-impact biomass system that does not compete with arable land and fresh water supply.

Launched in January 2010, the R&D program combines aquaculture, *salicornia* cultivation, mangrove silviculture, biomass processing, and the technology needed to enhance feedstock production efficiency in making sufficient quantities available, mainly for a sustainable biofuel production system. For the purposes of this assessment program, a demonstration, commercial-scale facility would also be built.[63]

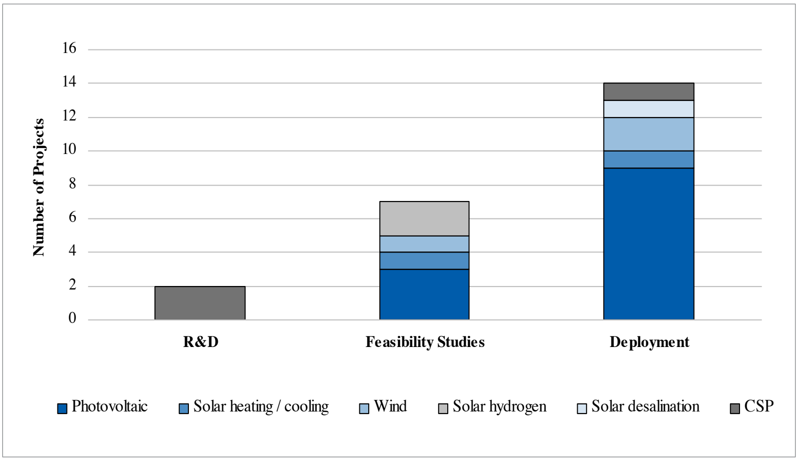
In addition to the obvious potential of solar power in the UAE, the drive behind exploring other renewable sources of energy translates into a healthy thirst for technological innovation in the country. This drive, fueled by a rich trade surplus and a healthy competition between the emirates, must be appropriately channeled to make it past the experimental phase. Faced with strategic challenges

62. Kazim, "Strategy for a Sustainable Development in the UAE," 2257-2269.

63. "Biofuel Research in the UAE" (Presentations during a conference by Masdar Institute on the sidelines of the World Future Energy Summit [WFES]), Abu Dhabi, January 19, 2011. See also: "Masdar Institute Completes First Sustainability Assessment for Biofuels Production from an Integrated Seawater Agriculture System, *Masdar Institute Media News* January 21, 2011at: http://www.masdar.ac.ae/inc/7/news.php?cboPage=11

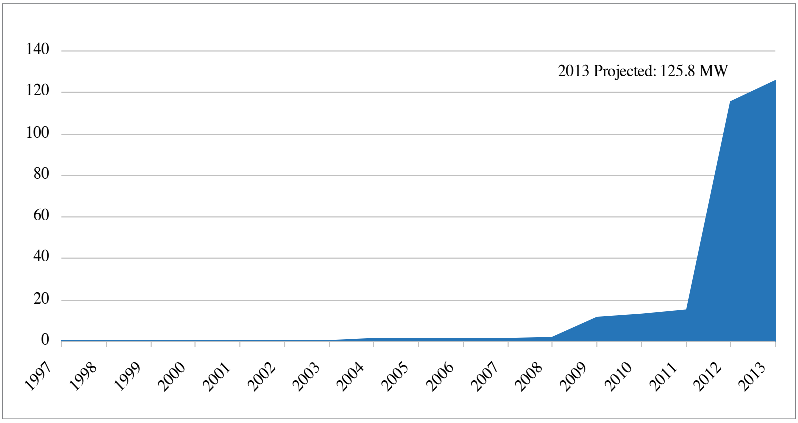
in its electricity sector, the country needs to coordinate all efforts to build its RE capacity, and not just buy and install it.

Number of Projects in the UAE per Nature and Technology (up to 2013)



Source: Author's calculation

RES Projects UAE - Cumulative Capacity (MW)



There are more than 23 RES projects in the UAE, of which 20 are designed to harness solar power. As a result of the UAE's interest in renewable energy innovation, 14 projects have already been deployed.
Source: Author's calculation

Renewable Energy Deployment and Market Potential

In addition to the R&D and demonstration projects, growing interest in RE technologies – mainly solar – is reflected in the size of installed capacity in the UAE. From less than 1 MW in 2004, the country is currently leading the GCC countries in terms of RE-based electricity generation. Initially, various small or demonstration projects have deployed photovoltaic and wind energy technologies in the country;[64] however, more recently, based on national or local strategies to promote eco-friendly development or to explore energy diversification possibilities, RE technical solutions or pilot projects were pursued. Small and large-scale solar projects have been designed, implemented or commissioned mainly by Abu Dhabi or Dubai authorities, and Ras Al Khaimah and Fujairah have also announced other future projects.

Put together, current deployments amount to 115 MW if we include the soon-to-be completed Shams1 CSP project; this capacity represents 68 percent of the total RES installed capacity in the GCC countries as of 2012; nevertheless, it still remains a fraction of the total capacity of fossil fuel based electricity generation in the UAE, which, at the time of writing, stands between 24 and 25GW. [65]

Prospects for Building-Integrated Photovoltaics (BIPV)

The volume of development and construction work that the UAE has undergone for the last 15 years or so has inspired some research on building sustainability as well as on building-integrating photovoltaic (BIPV) systems. Using an assessment tool that measures the performance of buildings in terms of their energy use per square meter and CO_2 emissions, a study by the Department of Architectural Engineering of the UAE University, has observed that average energy use/area in domestic (UAE) buildings is high (213 KWh/m^2) and that their CO_2 emissions are alarming. Public buildings showed even less sustainable features in terms of their energy performance and environmental impact.[66] Indeed, in 2009, the built environment (residential and commercial sectors) in the UAE consumed up to 70 and 74 percent of the total electricity consumption in Abu Dhabi and Dubai, respectively. Such

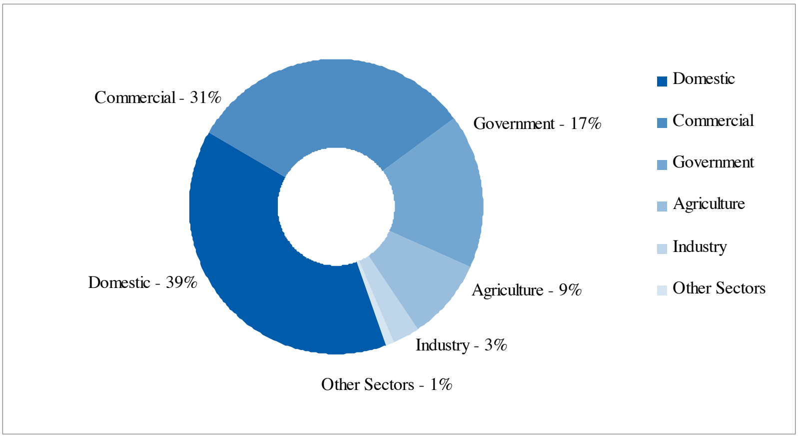
64. Like passive cooled shelters, PV power systems for GSM stations, PV powered pay phones, Integrated PV lighting, or the Sir Bani Yas island turbine, etc.

65. Author’s estimates, based on statistics from ADWEC, DEWA, SEWA, and FEWA.

66. Mohsen M. Aboul Naga, Yasser H. Elsheshtawy, “Environmental Sustainability Assessment of Buildings in Hot Climates: the Case of the UAE,” *Renewable Energy* 24 (2001): 553–563.

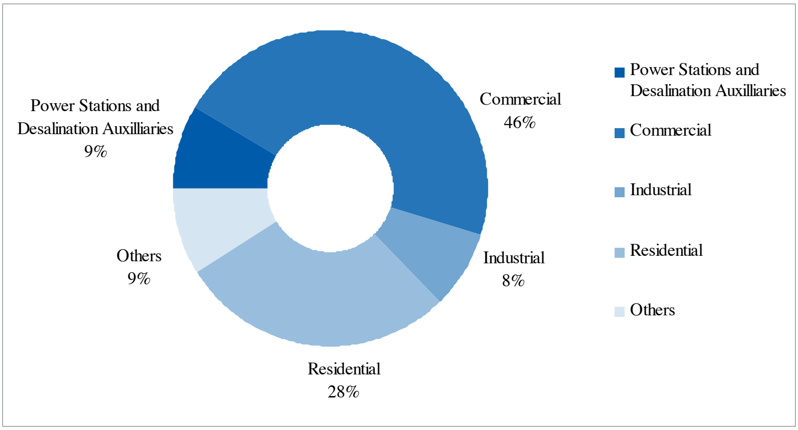
high consumption is partly due to the typical building's cooling needs in the region and partly because of the inefficient use of energy.[67]

Electricity Consumption by Sector (%) - Abu Dhabi



Source: Based on data from the Statistics Center of Abu Dhabi (SCAD)

Electricity Consumption by Sector (%) - Dubai



Domestic (or Residential) and Commercial represent 70 percent of total electricity consumption in Abu Dhabi and 74 percent in Dubai.
Source: Based on data from Dubai Electricity and Water Authority (DEWA)

67. These estimates are not available for the other emirates. Statistics Centre of Abu Dhabi, «Electricity Consumption by Sector» (2010): http://www.scad.ae/en/Statistics/Pages/SubTopicTableGraph.aspx?TabID=3&TGID=896&SubTopicID=121 and DEWA statistics: http://www.dewa.gov.ae/aboutus/electStats2010.aspx

In particular, energy sustainability and thermal insolation in UAE buildings were examined from the point of view of PV design – i.e., the integration of photovoltaic panels into the building's structures. Assessment of the technical performance and economic viability of PV panels as wall cladding system applied to commercial buildings was studied, and it was found that apart from the energy output of PV modules, additional energy savings can be gained over the BIPV system's life thanks to the PV panels' thermal insulating capacity in terms of heat transfer and cooling load.[68]

Such architectural designs are not yet deployed in the UAE; however, efforts to harness solar power in UAE buildings can be seen in the Pacific Controls Systems (PCS) headquarters in Dubai and, obviously, in Masdar City – a sustainable carbon neutral zone deploying RE technologies – that is still under construction on the outskirts of Abu Dhabi.

The PCS headquarters is the Middle East's first USGBC Leed-certified Platinum rated Green Building,[69] a fully automated 120,000 sq. ft. commercial building, completed in 2007. The building uses 50kW solar PV system for lighting and 100 tons of solar thermal air conditioning – that is 354 KW_t – to provide for 25 percent of its total cooling requirement.[70] Dubai authorities hailed PCS' accomplishment as an innovation that should be emulated by all subsequent real estate development of the emirate. However, it is important to emphasize that the focus is on the energy efficiency aspects rather than the solar lighting and cooling solutions as such.[71]

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68. The study concludes that taking into account savings in the building operational energy due to thermal insulation operated by the PV panels, the energy pay-back time (EPBT) is reduced from 12-13 years to 3.2-3.0 years; the study also comes to the general conclusion that the reduction in operational energy due to PV panels represents an important factor in the estimation of EPBT; Efficiency and orientations of the PV panels used in this simulation are also analyzed. See H. Radhi, "Energy Analysis of Façade-integrated Photovoltaic Systems," 2010.

69. USGBC stands for US Green Building Council and LEED for Leadership in Energy and Environmental Design, which is a rating system developed by USGBC.

70. The thermal air conditioning is supplied by absorption chillers that operate on solar flat plate collectors. The plant (375 KW_t) is one of the largest in the region and world to be commercially implemented in a 'real' environment, according to Dilip Rahulan, Chairman and CEO of Pacific Control Systems LLC in "Chilling With Sun", *Gulf News*, May 15, 2007; for more on the building's solar components and their automated operations, see Joanna Turpin, "A Platinum Oasis in the Desert," Engineering Section, Green Intelligent Building, available at http://www.pacificcontrols.net/news-media/GIB_12-07.pdf ; LEED Certification: PCS building website: http://pacificcontrols.net/news-media/news_19.html

71. Dubai's ruler Shaikh Mohammed bin Rashid Al Maktoum issued a decree in 2007 stating that residential and commercial buildings in Dubai must comply with green building specifications

Masdar City, initially designed as an extended clean-tech cluster comprising residential areas, offices and R&D facilities, currently consists of only the Masdar Institute of Science and Technology (MIST) and its student residences.[72] Nevertheless, these buildings integrate a rooftop 1 MW system of SunPower E19 solar PV panels that provides 30 percent of their electricity demand. The 10MW solar photovoltaic plant, built and connected to the Abu Dhabi grid in 2009 to power the construction activities of the city, also supplies the remaining electricity requirements of MIST buildings and the temporary Masdar headquarters buildings. Apart from photovoltaic electricity, 75 percent of the buildings' hot water is provided by rooftop thermal collectors.[73]

Masdar City, which is considered as a development that preserves the environment, however, has no binding interaction with Abu Dhabi's Estidama

and standards. See Arabian Business, "Dubai Green Building Rule", November 1, 2007; this also triggered the establishment of the Middle East Centre for Sustainable Development (MECSD) - under the supervision of PCS and the regulatory arm of Dubai World Environment, Health and Safety (EHS), to promote 'Green Building' certification under the USGBCs LEED rating system; EHS later developed its green building rating system: Wesdom; see Edmund O'Sullivan, "Dubai Meets the Green Challenge", Sustainable Development in the Gulf, *MEED* Supplement (2009). It is important to note here that Dubai had already established its Emirates Green Building Council (EGBC) in July 2006 and that EGBC had also developed a Building Sustainability Assessment Tool (BSAT) as an adaptation of LEED to the Emirates requirements with increased emphasis given to water conservation: http://www.emiratesgbc.org

72. See Tamsin Carlisle, "Masdar City Clips another $2.5bn from Price Tag," *The National*, December 1, 2010.

73. Currently, the city is fully powered by solar energy technologies deployed onsite (BIPV, Thermal collectors, or the 10 MW solar farm). However, as the city grows, only 20 percent of its overall energy supply will come from onsite deployments; the remaining power will be sourced from offsite renewable sources. See http://www.masdarcity.ae/en/60/sustainability-and-the-city/energy-management ; When first launched, Masdar City was to be constructed over six phases due for completion by 2016; however, the economic crisis and other financial considerations caused these plans to be revised in 2010, then again in 2011; for Masdar City original plan, see *MEED*, http://www.meed.com/supplements/2009/sustainable-development/masdar-is-the-city-of-the-future/3001853.article ; regarding the postponing of these phases, see: http://www.businessweek.com/news/2011-09-15/world-s-first-solar-building-exporting-energy-shelved-by-masdar.html ; The buildings' PV system is installed on a canopy structure that provides shade for the roof terrace. Residential units are also energy efficient, as they use 54 percent less water and 51 percent less electricity than average residences in the UAE; in http://www.solarthermalmagazine.com/2010/12/07/rooftop-solar-power-pv-system-in-masdar-city-one-megawatt; For general information on Masdar City, see their website: http://www.masdarcity.ae/en/27/what-is-masdar-city;

sustainability initiative, which has the "Pearl Rating System" (PRS) building codes according to which RE technologies constitute an optional credit point in the energy rating section.[74]

According to Sultan Al Jaber, CEO of Abu Dhabi Future Energy Company (ADFEC), or Masdar, the concept behind Masdar City should not be conflated with that of a real estate project. Through Masdar City, the company (ADFEC) is rather "trying to develop technology that will help secure better urban planning in the future, in a way that is energy efficient … [with] no impact on the environment... and from which the world can learn."[75] As such the city could be perceived as an R&D and Demonstration (RDD) program, testing a full range of sustainable, clean-tech and RE technologies, for future application.

For the present, however, both Abu Dhabi and Dubai green building codes have not made the specifications and standards compulsory for developers; nor did they assign specific governmental authorities to implement green building codes, provide incentives to developers who follow these codes, or penalize those who ignore them.[76] Electricity and water prices are subsidized in the UAE, which leads to extensive consumption and CO_2 emissions, especially in buildings. Yet, unless legislation enforces sustainable standards in general, or gives incentives to integrate RE for electrifying, heating or cooling systems in particular, there will be no changes in habits or widespread use of innovations in the near future.

Competitiveness of Solar Power

Deployment of RE technologies in the UAE also includes some utility-scale demonstration or pilot projects; these are either implemented or on course to be developed by Masdar (ADFEC) or DEWA.

Photovoltaic Plants

The first major utility-scale project that deployed solar technologies to generate

74. The PRS for buildings covers many sections including water, energy and waste minimization, local material use and supply of sustainable and recycled materials and products. Estidama is developed by the Abu Dhabi Urban Planning Council (UPC). More information on: http://www.estidama.org

75. Excerpts from S. Badih, "Masdar - A Green Vision for a Better Future," *Gulf News*, November 24, 2011.

76. On implementation of green buildings regulations in Dubai, see Vesela Todorova "Green Code on Hold to Boost Building," *The National*, April 20, 2011: http://www.thenational.ae/news/uae-news/green-code-on-hold-to-boost-building.

electricity in the UAE was the 10MW photovoltaic power plant built to serve as a demonstration project for the region and to power the construction of nearby Masdar City.[77] The plant is one of five projects registered by the UAE for carbon credits under the United Nations' Clean Development Mechanism (CDM). According to the CDM Project Design Document (PDD), the solar PV plant should generate at least 17,564MWh per year, with electricity generation cost of $117/MWh,[78] including operating cost of $10/MWh during the 30 years of its lifetime. There are no returns on investment expected in these calculations, as the project activity was designed to be used as a demonstration project for other developers in the region.

The Masdar City plant employs 50 percent thin film and 50 percent crystalline silicon panels. It was originally announced that the plant would achieve annual carbon savings of 15,000 tons in CO2 emissions, but two years later Masdar confirmed savings of only 24,000 tons in total. This discrepancy could be due to a lower technological performance than expected, hence pointing to the technical uncertainties of RES in the local environment in particular. Nevertheless, it was acknowledged that a certain expertise has been gained through the monitoring of the R&D activities around the plant, which is valuable for other utility-scale PV projects in the region.[79] Connection of the plant to the Abu Dhabi electrical grid, which actually took place in May 2009, was supervised by the Abu Dhabi Distribution Company (ADCC) and the Regulation and Supervision Bureau. The latter, which regulates and awards licensing for power generation sources in Abu Dhabi, supplied Masdar (ADFEC) with its first license for renewable energy power.

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77. Renewable energy projects of a capacity less than 15 MW are classified by the Clean Development Mechanism's Executive Board as small-scale CDM projects. A local company, Enviromena Power Systems, was commissioned to design and construct the grid connected PV plant, the total cost of which reached $50 million, see CDM Executive Board, *CDM Project Design Document ADFEC 10 MW Solar Power Plant*, available at http://cdm.unfccc.int/Projects/DB/SGS-UKL1237544831.86/view ; and Enviromena Power Systems website: http://www.enviromena.com

78. This price was estimated to be three times costlier than the then prevailing electricity price for commercial consumers. See CDM Executive Board, *CDM Project Design Document ADFEC 10 MW Solar Power Plant*, 15.

79. "Masdar Connects 10MW PV Plant To Abu Dhabi Grid," May 31, 2009 in http://www.masdar.ae/en/MediaArticle/NewsDescription.aspx?News_ID=125&News_Type=PR&MenuID=0&CatID=64 ; Masdar press release, "Masdar City's Solar Power Plant is Net Exporter of Energy to UAE," June 8, 2011, in http://www.masdar.ae/en/MediaArticle/NewsDescription.aspx?News_ID=202&News_Type=PR&MenuID=0&CatID=64

More recently, Masdar Power engaged in the development of the 100MW PV power plant Noor 1. For this project, Masdar (ADFEC) requested that the engineering, procurement and construction (EPC) contract include that 50 percent of the panels use Masdar PV company's thin film modules that are produced in Germany. As per Masdar PV's website, these panels are constituted of double layered amorphous silicon thin films with three junctions instead of the customary two junctions and their efficiency stands at 7.4 percent.[80]

However, whereas ADFEC announced in May 2011 that the Masdar City 10MW PV power plant has met all its targets,[81] it is perplexing that untested technology would be considered for a large-scale solar power plant such as Noor 1. In particular, First Solar's thin film technology used in the demonstration plant has a nominal efficiency that ranges between 9.7 and 10.8 percent, which is higher than that of Masdar PV modules proposed for Noor 1. According to business intelligence reports, uncertainty around the technology is discouraging developers from bidding in a renewable energy project of this size involving high technology risks.[82]

In Dubai, another solar deployment using PV technology was announced recently. The project, Mohammed Bin Rashid Al Maktoum PV Plant, is to be implemented by DEWA within the UN CDM framework and will deploy 10MW of thin film-PV modules. Based on local assessment of the solar irradiation, and taking into account the wind and dust effect, it has been decided that the plant would be located in the desert area in the south-east of Dubai, bound by Al Ain Road and the Abu Dhabi truck road. As per the project design documents filed with the Clean Development Mechanism (CDM) administration, the plant to be connected to the DEWA grid will generate 15.743GWh per year and will prevent 8,115 tons of CO_2 from being released annually in the atmosphere. The project's estimated cost was said to be around Dh109 million.[83]

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80. Masdar PV, Press release June 2010, in Masdar PV website: http://www.masdarpv.com/286.html?&L=1&tx_ttnews[tt_news]=86&tx_ttnews[backPid]=395&tx_ttnews[pointer]=1&cHash=78f79b2ca8; for different thin film technology efficiencies, see T.M. Razykov, C.S. Ferekides, D. Morel, E. Stefanakos, H.S Ullal, "Solar Photovoltaic Electricity: Current Status and Future Prospects," *Solar Energy* 85 (2011): 1580-1608.

81. Masdar press release "Masdar City's Solar Power Plant is Net Exporter of Energy to UAE," June 8, 2011.

82. MEED: http://www.meed.com/sectors/power/renewable-energy/masdar-insistence-puts-bidders-off-abu-dhabi-solar-project/3108122.article and http://www.meed.com/sectors/power/renewable-energy/contractors-submit-bids-for-abu-dhabis-noor-1-solar-plant/3108045.article

83. Information remains incomplete till the land use permit is issued and the project tendered by

The 10 MW project was presented as a first step towards the emirate's target to produce five percent of its total electricity needs by 2030 from solar energy, thus amounting to 1,000 MW.[84] In 2011, the Dubai Supreme Council of Energy unveiled an 'Integrated Energy Strategy 2030' where besides solar, clean coal and nuclear would be part of the emirate's energy mix by the year 2030.

Prior to that, Abu Dhabi had also announced that seven percent of its total energy by 2020 would come from RE technologies. This was revised only recently, but Masdar power projects such as Noor 1 and Shams 1 – the latter is being implemented and will be discussed in the subsequent section – were developed to help the emirate meet this target.[85]

However, in the absence of a general legal framework for utility-scale RE deployments – like feed-in tariff regimes – Dubai, like Abu Dhabi, can face some investment barriers, and their major solar projects are likely to be - like in the Shams1 deployment – government schemes or else driven by significant subsidies. Indeed, the standard conventional electricity tariffs that incorporate the government subsidy range between a minimum of US cent 6.2/KWh for residential and commercial sectors to US cent 10/KWh for industrial and governmental sectors in Dubai, and they range between a flat minimum of USD cent 0.8/KWh (for national residents) to a flat maximum of USD cent 4/KWh (for expat-residents, industrial or commercial sectors) in Abu Dhabi. [86]

Evidently these tariffs do not reflect the real cost of the electric unit. Produced in a typical GCC utility – a natural gas combined cycle plant – and with a market fuel price of $7.2/MBTu, a unit of electricity – 1 KWh – was roughly estimated to cost USD cent 12/KWh.[87] Hence, judging from the cost of electricity from Masdar

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DEWA and its partner - Dubai Carbon Centre of Excellence (DCCE). The CDM Project Design Document of the Mohammed Bin Rashid Al Maktoum 10 MW PV Plant is available on the UNFCC CDM website at: http://cdm.unfccc.int/Projects/Validation/DB/N2XPSCFQ0OAK62JS1A79WLSFTDDC7X/view.html ; see also Vesela Todorova, "Dubai to Cut 1.7m Tonnes of Carbon," October 6, 2011 at http://www.thenational.ae/news/uae-news/environment/dubai-to-cut-1-7m-tonnes-of-carbon

84. Zawya, "Dubai Launches AED12B Solar Power Project in Push Towards Renewables," January 9, 2012.

85. Statement by Sultan Al Jaber, CEO of Masdar, in Florian Neuhof, "Shams I Gets Out of the Blocks," Utilities ME; June 9, 2010.

86. Dubai electricity tariffs are obtained from DEWA, http://www.dewa.gov.ae/tariff/tariffdetails.aspx, and Abu Dhabi electricity tariffs are obtained from the emirate's Regulation and Supervision Bureau's available at: http://www.rsb.gov.ae/uploads/InfoElecTariffsLargeUsersNov09.pdf

87. According to this study, a GCC utility typically pays $1/MBTu, making the government fuel and

10 MW solar projects, where the cost of electricity amounted to US cent 11.7/KWh,[88] investors in RE energy utility sector in both the emirates will need to be compensated for any price difference. Such compensation was indeed put in place for Masdar-Power CSP Plant.

Shams CSP Plant

Through its utility-scale projects developer (Masdar Power), Masdar (ADFEC) has also ventured with Abengoa Solar and Total to develop a 100MW CSP plant. Called Shams 1, this plant is one of two large-scale deployments that Abu Dhabi is developing inside the UAE.[89] The project was also filed and got validated as a CDM for its potential contribution to sustainable development in the UAE; it is located at Madinat Zayed, 116 km southwest of Abu Dhabi city, and is scheduled for completion by the end of 2012 or the beginning of 2013.

Shams 1 consists of a solar field comprising 624 solar collector assemblies (SCA), where 2,496 parabolic trough shaped mirrors focus sunlight on heat collecting tubes that contain the heat transfer fluid. The temperature in the tubes ranges from 293ºC to 393ºC, where the heat transfer fluid, typically oil, is circulated from the solar field to the steam generation system of the power plant to feed the steam cycle of steam turbines. The Shams 1 solar field is designed to normally supply 286 MW_{th} of thermal energy, which corresponds to gross power generation of 100MWe.[90]

As the quantity and temperature of water heated by solar - in the steam generation system for the steam turbines - will depend on the solar radiation, and given the fact that the latter will vary with season and time of day, the required level

distribution subsidies reach US cent 8/KWh when the end-consumer pays US cent 4/KWh; see Booz & Co. *A New Source of Power: The Potential for Renewable Energy in the MENA Region* (2010), 15.

88. See CDM Executive Board, *CDM Project Design Document ADFEC 10 MW Solar Power Plant*, 15, see footnote 79.

89. In addition to Nur1; outside the UAE, Masdar Power has ventured into RE international projects and markets like the 1,000 MW London Array offshore wind farm; the company also invests in technology relevant to utility-scale renewable energy. See Masdar website: http://www.masdar.ae/en/Menu/index.aspx?MenuID=48&CatID=29&mnu=Cat

90. In Shams 1, the steam turbine used is 120 MVA, however due to load variation its output will be 95,806 MW. For detailed information on this and on the different units and phases of this project process, see CDM PDD of Shams 1 available on the UNFCC CDM website at: http://cdm.unfccc.int/Projects/DB/SGS-UKL1240326340.92/view

for steam generation will be supported by natural gas auxiliary firing, for boosting purpose only. It is estimated that of the 231 GWhe of power generated by Shams 1, the solar field will generate 68 percent while direct firing of natural gas will provide the remaining 32 percent.[91]

The feasibility study performed for this project compares Shams 1 output with a reference combined cycle power plant with similar capacity and finds that the levelized Electricity Generation Cost (LEC) from Shams 1 is almost six times bigger than the reference plant, that is $157/MWh (or 16 USD cents/kWh) and $27/MWh (or 3 USD cent/KWh), respectively, in the base case scenario. These costs [base case scenario] are based on subsidized prices set by the Abu Dhabi government for natural gas – i.e., 6.63 AED/MBTU instead of market price of 25 AED/MBTU. If on the contrary one considers the MBTU market price, Shams 1 LEC would be lowered to 12-14 USD cent/KWh whereas for the reference combined cycle plant, LEC would rise to 5.6 USD cent/KWh.[92]

Furthermore, it should be noted that the Shams' LEC does not take into account the CO_2 avoidance cost. Indeed, as the electricity delivered to the Abu Dhabi grid by Shams 1 solar field would have otherwise been generated by fossil fuels (mainly gas), the project would reduce pollutants' emissions by 174,977 tons of CO_2 annually (tCO_2/annun). Hence, according to the expected CDM revenues for this project, which could amount to $40 per ton of CO_2, one can consider that the Shams 1 project should cut its LEC by 3 USD cents for each KWh produced - in any scenario – for every year of the crediting period.[93]

At any rate, for the Shams 1 project, the deployment has been made possible thanks to a 25-year power purchase agreement signed between the developers[94] and

91. The quantity of natural gas required is estimated at 13548387.1 SCM (Standard Cubic Meter); CDM Executive Board, *Clean Development Mechanism, Project Design Document (CDM PDD) Abu Dhabi Solar Thermal Power Project, MASDAR*, Version 06, 13/08/2009; p.8.

92. The feasibility report for Shams 1 was prepared by Fichtner Solar Consultants. For information on the investment as well as the sensitivity analyses provided, see the *CDM PDD Abu Dhabi Solar Thermal Power Project,* 15 -20.

93. As Shams 1 project will use natural gas auxiliary firing, the project emissions will amount to 28,534 tons of CO_2/annum. For all details concerning the expected CDM revenues by the project proponents, see *CDM PDD Abu Dhabi Solar Thermal Power Project, MASDAR*, Version 06, 13/08/2009, 22 and 31. Shams1' LEC reduction in this case is based on author's calculations.

94. The project sponsors, Abengoa and Total, each hold a 20 per cent stake, and Masdar Power holds the remaining 60 per cent; Construction of Shams 1 project began with some delay in the 3rd quarter of 2010 instead of 2009; See Andrew Roscoe, "Masdar Awards Shams 1 Solar Project Contract," *MEED*, June 9, 2010; available at: http://www.meed.com/sectors/power/renewable-

the government of Abu Dhabi, as well as the guarantee by the latter of the debt associated with its financing scheme.[95]

In this regard, the electricity generated in the Shams 1 hybrid scheme is supported by both standard subsidies (including for fuel and distribution, etc.) and the payment of an additional premium by Abu Dhabi authorities to RE producers,[96] which weighs considerably on the budget of the government. In this sense, Shams 1 project may point to the unsuitability of such financial investment schemes for other governments (in the UAE or in the whole region) as well as to their non-sustainability in terms of increasing the number of large RE deployments in the future.

Indeed, although the Abu Dhabi government compensation comes close to the feed-in tariffs applied in other countries, maintaining subsidies for fuel based electricity and introducing new RE subsidies further drains government financial resources. In the present context, it would be politically difficult to withdraw these conventional subsidies, especially after the reinforcement of such benefits in all GCC countries following the events of the Arab Spring. So, even if a FIT mechanism is introduced, the cost of a solar (and RE in general) unit of electricity must come down to parity with the cost of non-subsidized fuel-based electricity, so the difference will not play against supporting RE generation. In this regard, multiplication of RE power projects in the UAE – and all GCC countries – will greatly depend on how related technologies become cheaper and more efficient.

At any rate, purpose and determination may be gauged from the relative wealth of cases where RE solutions have been attempted in the UAE. Indeed, these were achieved, despite their related costs, a position that is endurable only on a limited scale and for a limited time, even in an oil-rich country.

BIPV and solar power plants are all relevant opportunities for the UAE and for every country in the GCC. However, beyond their demonstrative benefits, the country's technological initiatives in the RE sector will need to make economic sense

energy/masdar-awards-shams-1-solar-project-contract/3007064.article

95. Indeed financing of the Shams1 project necessitated a debt of $615 million lent by 10 commercial banks; the remaining capital input – $153 million – is supplied by Abengoa and Total in equity; see Verity Ratcliffe, "Shams 1 Solar Project Reaches Financial Close," *MEED*, March 6, 2011; available at: http://www.meed.com/sectors/power/renewable-energy/shams-1-solar-project-reaches-financial-close/3089487.article

96. Nick Carter, Director General of the Abu Dhabi Regulation & Supervision Bureau, calls this 'green pricing mechanism'; see Florian Neuhof, "Shams I Gets Out of the Blocks," *Utilities ME*, June 9, 2010: http://www.utilities-me.com/article-582-shams-i-gets-out-of-the-blocks

in order to become real innovations that address the nation's energy imperatives.

Investing in Technology

According to Sultan Al Jaber, CEO of ADFEC-Masdar, Shams 1 project is expected to help [...] lower the costs of future projects. But not only will such large deployment "open the doors for renewable energy projects in the UAE" it will also allow [Masdar] "to transfer to Abu Dhabi the know-how and expertise we have gained from our involvement in developing world-class renewable energy projects abroad."[97]

It is worth mentioning here that the Masdar (ADFEC) initiative, which is a wholly owned company of the government of Abu Dhabi through the Mubadala Development Company, is a commercially driven enterprise that is structured around five integrated entities – Masdar City, Masdar Institute, Masdar Capital, Masdar Carbon, and Masdar Power – in order to have a holistic approach to clean and renewable energy infrastructure, networks, markets and systems. In summary, Masdar operations revolve around:

- Attracting global renewable energy and clean tech companies to Masdar city
- Investing in research that stimulates innovation and generates intellectual property gains
- Investing in promising renewable energy and clean technology companies
- Reducing carbon emissions through energy efficiency and carbon capture and storage
- Developing and operating strategic utility-scale renewable power generation projects.[98]

In this approach, the Masdar leadership aims to maintain Abu Dhabi's global positioning in the energy sector, by providing the emirate with a "robust platform for human capital development in a field that is new", "reinvesting [oil] revenues into securing the future of energy", and "tapping into established regulatory frameworks that support green power or renewable energy to tap into the expertise, into the knowledge and to bring in the best technologies."[99]

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97. Excerpts from Neuhof, "Shams I Gets Out of the Blocks," *Utilities ME*, June 9, 2010.
98. ADFEC Masdar was established in 2006; more on its units and programs can be found on their website: http://www.masdar.ae
99. Excerpts from Samiah Badih, "A Green Vision for a Better Future," *Gulf News*, November 24,

Hence, in parallel with R&D activities led by MIST and its research network on CSP beam-down technology, and with the development of Shams 1 that uses the CSP parabolic trough technology, Masdar Power has partnered with Spanish SENER in a joint venture called Torresol Energy to build Gemasolar IPP plant in Seville, Spain. The project uses CSP solar tower technology developed by SENER and has a capacity of 19.9MW. In particular, the solar tower technology deployed at the Gemasolar Greenfield uses molten salt as a heat transfer medium, a receiver technology that is considered an innovation; it is capable of storing and producing energy for 15 hours without sunlight, thus ensuring generation of electricity 24 hours a day and increasing the performance of the overall CSP plant.[100]

Masdar Power's investments in foreign regulated markets may prove essential in advancing RE technologies tested, developed and monitored outside the UAE; they could also accelerate RE deployment in the country. Indeed, based on the experience acquired in Spain and Abu Dhabi, Masdar Power through Torresol intends to promote the central receiver tower system, or parabolic trough technology.[101] In 2011, Masdar Power discussed with the Torresol to build a similar solar tower power plant in Abu Dhabi.[102] According to the CEO of Masdar, Gemasolar was the right investment and yielded the right technology to tackle the intermittency problem of the solar energy. It has proved that solar power is a reliable option.[103]

However, it is obvious that the company's commercial approach is in contrast with Masdar Institute's emphasis on local research capacity development, where

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2011.

100. Founded in 2008, Torresol Energy is a 40:60 Masdar-SENER joint venture. The company that commercially develops, manages construction, owns and operates CSP plants globally has been awarded a 25-year regulated tariff by the Spanish Government; in "Torresol Energy Commissions 19.9MW Gemasolar Power Plant in Spain," thefuturebuild.com, May 24, 2011, available at: http://www.thefuturebuild.com/torresol-energy-commissions-19-9mw-gemasolar-power-plant-in-spain-27587/news.html

101. Torresol Energy also owns the Valle 1 and Valle 2 plants – currently under construction in Spain –that will employ parabolic trough technology and have a power generation capacity of 50MW each; in "Torresol Energy Commissions 19.9MW Gemasolar Power Plant in Spain," thefuturebuild.com, May 24, 2011.

102. The capacity of the Abu Dhabi Solar Tower plant is not known yet., also see Verity Ratcliffe, "Masdar Considers Building Solar Power Tower in Abu Dhabi," *MEED* Issue 18,May 6-12, 2011: http://www.meed.com/sectors/power/renewable-energy/masdar-considers-building-solar-power-tower-in-abu-dhabi/3096039.article

103. Statement of Sultan Al Jaber, Chief Executive Officer of Masdar, in "Masdar: The Challenges We Face Making Green Energy Viable," *The National*, October 2, 2011.

local 'researchers [should] learn how to build pilots…evaluate the technology's effectiveness in Abu Dhabi's weather conditions, develop intellectual property and explore ways to convert it to commercial scale.'[104] In this sense, in addition to education, MIST is expected to generate research and ideas which would lead to technology-based industries. However, what the example of Masdar Power Gemasolar investment shows is that by acting as a global leader, one may harness more easily the power of innovation through ventures and that transfer of technology could happen through owning intellectual property, which creates a wealth of knowledge for the economic fabric of the country.

On the other hand, as described earlier, multiple R&D initiatives, demonstration projects, and small and large deployments have explored solar power technologies and their applications in the UAE; these proved that solar energy is poised to be the main source of RE power in the country. However, taking into consideration the multiplicity of initiatives and investments, and the fact that research and technological development is very expensive, it is important that efforts be integrated at a national level and focused on strategic areas of development all over the UAE. Combined with innovation policies, such efforts should be channeled towards purposeful, economically viable RE solutions. This way resources are optimized so to avoid waste or redundancy within the same enterprise, emirate, or among the different emirates.

The weight on resources caused by industrial and population growth put pressure on the country's ability to meet its domestic needs in desalinated water, air-cooling and agricultural products. In this sense, solar desalination or building integrating PV can alleviate electricity consumption in these sectors and prove to be a sustainable solution too. As the UAE's institutions work with international industry leaders in the development and deployment of RE technologies, projects should be tailored to answer the country's specific needs. Moreover, water scarcity, food security, fuel shortages and electricity blackouts constitute critical issues that differently affect the seven emirates. So RE investments and development should be devised according to local priorities, land availability or financial resources. For instance, with its large capital resources, Abu Dhabi can indeed afford the high upfront capital cost of large RE projects, as the emirate produces up to 46 percent of UAE's electricity peak demand[105] RE technologies can be deployed to mitigate

104. Tariq Ali, Vice President for research at the MIST, in Stanton, "Masdar's New Slant on Solar Energy."

105. Author's own calculation for 2010 based on peak demand statistics for the UAE compiled by GRC.

the seasonal peak and reduce emissions of greenhouse gases.

All the same, the proliferation of utility-scale RE projects will also and primarily depend on political will. With the right support policies and investment-friendly environment, local deployment of RE technologies can increase. Further, this could also help transfer know-how and expertise to the country through building, operating, monitoring and upgrading such deployments. Hence, if such deployments multiply, supply of components will be needed, related industries will flourish and micro-innovations will be induced. As the Masdar leadership concedes, in addition to Masdar Power investment in SENER solar tower technology, "Marketplace incentives such as feed-in-tariffs and renewables obligations will 'also' be required to drive adoption of molten salt storage."[106]

Certainly, innovation and technological breakthroughs make deployment of RE applications more probable in the UAE and the rest of the GCC countries. However, for these technologies to succeed they will need a proper economic environment to demonstrate their economic value; for this, policy-makers and governments need to create the appropriate legislation and regulatory frameworks.

Targets and Future Energy Mix

Despite ambitious RES-based deployment projects and other promising R&D and investment initiatives, RE electricity would account for only about 7 percent of Abu Dhabi's total projected capacity by 2030 – instead of the 2020 time limit previously announced by the government.[107] Forecasts for 2030 are not available; however, according to ADWEC, peak demand could reach 22,356MW forAbu-Dhabi's system only, or even higher if we include exports (28,188MW).[108] Hence, the announced 7 percent by 2020 means that at least 1,565MW of the Abu Dhabi system should be RES-based.

106. Sultan Al Jaber, CEO of Masdar, "Masdar: The Challenges We Face in Making Green Energy Viable."

107. Federal Authority for Nuclear Regulations (FANR) http://fanr.gov.ae/ar/media/get/20090430_uae-policy-white-paper.pdf and Bloomberg, "Abu Dhabi Pushes back Green Energy Goal to 2030," January 17, 2012 available at http://www.arabianbusiness.com/abu-dhabi-pushes-back-green-energy-goal-2030-440945.html

108. ADWEC forecasts point to the possibility that the Abu Dhabi global system could account for 70 percent of the total country peak demand by 2020, in case we consider that the UAE peak demand in 2020 would amount to 40,000MW; Abu Dhabi forecasts are from Miller et al. "ADWEC Winter 2010/2011 Demand Forecast 2011-2030," 13 and 25.

In the meantime, the country is going ahead with its nuclear plan even after Japan's Fukushima plant caused a halt in other atomic programs in the region.[109] Abu Dhabi has allotted resources for building four nuclear reactors in the emirate, with a capacity of 1.4GW each, all of which should be functional by 2020.

The authorities also estimate that enough volumes of local natural gas could be made available to meet 20 to 25GW of power generation capacity by 2020. Nevertheless, if we add the 5.6GW of nuclear energy and consider the lowest demand prospects, i.e., 33GW instead of 40.85, the UAE will still need at least 2.4GW of alternative energy based capacity. This figure closely corresponds to 7 percent of the total UAE lowest projected capacity by 2020.

Naturally, continuous socio-economic expansion and related energy consumption will drive over-exploitation of natural resources (oil, gas, water), which will exacerbate the environmental risks in the country. Faced with such a challenging situation, UAE authorities have announced strategic priorities. Nuclear power is one strategy that will bear a significant weight in addressing the electricity security imperative but that comes with its own issues – finite uranium resource, nuclear waste management and the permanent risk of accidental release of radioactive materials[110] – even though the nuclear option, in comparison to coal, has been justified by the authorities as an environment-friendly option.

However, renewable energies and energy conservation policies are other strategic priorities, for which the country has great hopes. Indeed, the forecast for the UAE needs in terms of electricity and water production capacity by 2020 still creates opportunity to integrate the clean renewable energy technologies – especially solar – into the country's future energy mix.

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109. *Gulf News*, "UAE Moves Forward with International Atomic Energy Agency," December 6, 2011:http://gulfnews.com/news/gulf/uae/government/uae-moves-forward-with-international-atomic-energy-agency-1.945065 ; The UAE is also connected to the Gulf Cooperation Council Interconnection Grid (GCCIG); however, the peak capacity of the GCCIG will barely ease the increasing pressure for electricity generation in the UAE; Basic statistics on the capacity of the GCC grid are available on the Saudi Arabia based GCC Integration Authority's website at http://www.gccia.com.sa/ ; in it is reported that the peak capacity of the GCCIG is 400MW. However, news reports have stated that UAE is to receive 900 MW of electricity through this grid. http://gulfnews.com/business/features/power-grid-brings-gcc-economies-closer-1.798660

110. David Elliott, "Sustainable Energy: Nuclear Power and Renewables," in *Sustainable Energy Opportunities and Limitations*, edited by David Elliott (Palgrave Macmillan 2007), 3-24.

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About the Author

Imen Jeridi Bachellerie coordinates the Science & Technology research program at the Gulf Research Center (GRC). She holds a degree in Electro-Mechanical Engineering from Ecole Nationale d'Ingénieurs of Tunis (Tunisia), a Master of Science in Mechanics from Ecole Normale Supérieure de Cachan (France), and a Master of Science in Epistemology and History of Science and Scientific Institutions from Université Denis Diderot-Paris VII (France). Imen Jeridi's research interests include science and technology research policies, science and engineering education, and industry-university linkages in the Arab World. She has participated in several international seminars, workshops and conferences on these topics. Her recent publications include: "Knowledge Creation and Diffusion: the Role of UAE Universities," "Science and Technology: Future Applications, Trends and Impact," and "Framework for a Renewable Energy Transition in the GCC: Finding the Right Paradigms."

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