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Renewable energy in the GCC: status and challenges

Rabia Ferroukhi and Noor Ghazal-Aswad
Policy Advisory Services and Capacity Building Directorate, International Renewable Energy Agency, Abu Dhabi, United Arab Emirates
Stella Androulaki
Decision Support Systems Laboratory, School of Electrical & Computer Engineering (NTUA), Athens, Greece, and
Diala Hawila and Toufic Mezher
Masdar Institute of Science and Technology, Abu Dhabi, United Arab Emirates

Abstract

Purpose – The purpose of this paper is to investigate the efforts undertaken by the Gulf Cooperation Council (GCC) countries in deploying renewable energy (RE), in terms of capacity assessments, research and development activities, and current and planned projects. The paper also aims to investigate the drivers and barriers for the diffusion of RE technologies in the GCC.

Design/methodology/approach – The paper provides a literature-based study on the status of the RE sector in the GCC, including capacities, projects, policies and frameworks in the GCC, in addition to an analysis of the main drivers and barriers to RE deployment arising from the literature.

Findings – The results of this paper illustrate growing interest in renewable energy in the GCC countries at the R&D and project implementation level.

Originality/value – The paper contributes by the provision of the latest knowledge on the status of the RE sector in the GCC and by highlighting the most significant drivers fuelling RE deployment, as well as the barriers currently hindering the greater diffusion of RE technologies in the region.

Keywords Gulf Cooperation Council, Renewable energy, Policy, Persian Gulf states

Paper type General review

1. Introduction

In a region in which economies are dominated by the oil and gas industries it may seem quixotic to invest in renewable energy technologies (RET). Critics would argue that such investments do not create adequate short-term financial returns and actually create competitors for the region's main exports. But such arguments are based on short-term considerations and ignore the huge emerging opportunities. Global energy prices have been high for much of the last decade and income from oil and gas exports

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in the Gulf Cooperation Council (GCC) region is at record levels. Nevertheless, dependence on oil and gas revenues is declining as GCC economies diversify (Flamos *et al.*, 2012). As this process continues, it is in the region's interest to invest in, and develop, the industries and capabilities of the future.

Similarly to other areas of the world, one of the main challenges faced by the development of renewable energy (RE) is the relatively cheaper price of conventional energy. However, this comparison generally fails to account for two factors: the significant subsidies that conventional energy sources enjoy in the GCC region and the external costs of using fossil fuels for power generation, including environmental cost and opportunity cost. GCC governments subsidize conventional power to stimulate economic growth and distribute the national wealth derived from oil and gas production, providing conventional power with a significant advantage over RE. However, these subsidies give conventional power a significant unnatural advantage over RE and act as an automatic brake on private investment in the sector, making RE compete with energy sources that are already cheap and widely available (El-Husseini *et al.*, 2009).

However, the GCC countries have recently shown a keen interest in engaging in a more sustainable development path, including the deployment of RE. In fact, there is a strong strategic and economic case for RE, based on the abundant resources in this region, the finite nature of hydrocarbon resources, the rapid development of RET and the global drive to reduce greenhouse gas emissions (Flamos, 2010). In addition, heavily subsidized, rapidly growing domestic energy consumption in the GCC reduces hydrocarbons export volumes and revenues. Various initiatives have been developed in the GCC and major RE projects have stated implementation, demonstrating the commitment and support of the GCC states to tap into alternative sources. Research and academic institutions throughout the region have conducted a thorough investigation on RE innovative technologies in order to acquire expertise and bring sustainable energy development concepts to "real life" applications. Masdar City in UAE aims to be one of the most sustainable cities in the world; The city will occupy approximately 6 km^2 and is an emerging global clean-technology cluster that places companies in the heart of the global RE and cleantech industry (Alusi *et al.*, 2011). Solar and other alternative energy sources figure prominently in the research agenda of institutions such as the King Abdulaziz City for Science and Technology (KACST) and the King Abdullah University for Science and Technology (Hertog and Luciani, 2009).

Based on such developments, the indication emerges that GCC nations address RE deployment as an important challenge and are willing to carve a pioneering path to the future of energy sustainability. In addition, some GCC countries aim to prepare their capability at the Research and Development (R&D) level to also position themselves in terms of RET production instead of remaining just energy consumers.

Several studies exist in the international scientific literature related to the possibility of adopting RET in different regions around the world. Carley (2009) provides an analysis for the evaluation of the effectiveness of state energy programmes with an empirical investigation of the linkage between state Renewable Portfolio Standards policy implementation and the percentage of RE electricity generation across the USA. Johnstone *et al.* (2008) examine the effect of environmental policies on technological innovation in the specific case of RE. The analysis is conducted using patent data on a panel of 25 countries over the period 1978-2003. Marques and Fuinhas (2011) study the commitment to RE, focusing on a set of 24 European countries, and applying panel

dynamic estimators. Sovacool (2009) through using interviews with public utility commissioners, utility managers, system operators, manufacturers, researchers, business owners and ordinary consumers demonstrates that the impediments to renewable power are socio-technical, a term that encompasses the technological, social, political, regulatory and cultural aspects of electricity supply and use. Through this process it is revealed that these socio-technical barriers are responsible for not universally embracing wind, solar, biomass, geothermal and hydroelectric power sources. Holm *et al.* (2008) provide an overview of the potential contribution of RE to rapidly and cost-effectively address South Africa's power crisis, foster a ground swell of domestic industries with sustainable work opportunities and contribute to meeting international commitment to climate change mitigation.

Several studies in the related scientific literature identify the potential of the GCC region to transit to a more sustainable and environmental friendly energy status. Alnaser and Alnaser (2011, 2009) have highlighted the solar and wind energy potentials in the GCC countries. The authors have also listed the major RE projects (mainly solar and wind) in each of the six GCC countries and have proposed a mechanism to accelerate the RE utility in these countries. Alnaser *et al.* (2007) have investigated the potential of concentrated solar power (CSP) in the GCC countries while Alnaser *et al.* (2008) have depicted the potential of making-over to sustainable buildings in the Kingdom of Bahrain with the exploitation of RE. Alawaji (2001) focuses on R&D in the sector of solar energy in Saudi Arabia. The author evaluates two major international R&D joint activities in the sector of solar energy aimed at developing RET. Hepbasli and Alsuhaibani (2011) address current applications and future aspects of solar energy along with studies conducted in this field and to assess them in the light of available sustainable energy technologies towards establishing energy policies.

From a policy perspective, Reiche (2010a) discusses the capacities of the GCC states to switch towards an ecological modernization of their energy sectors. The author analyses the benefits of transforming oil wealth into funding for RE and energy efficiency and discusses obstacles to such a transformation process based on the rentier states theory. The author also investigates the governance of the GCC on international, regional and local level. The smooth cooperation of the EU and the GCC key energy players is considered important for the challenging objective to engage GCC countries in a more sustainable development path (Doukas *et al.*, 2012; Flamos *et al.*, 2010).

Alawaji (2000) reviews and evaluates R&D efforts and applications of RE in Saudi Arabia based on the technical and economical feasibility. The author further presents the policy of the country regarding the future utilization of RES and their effective commercialization. Doukas *et al.* (2006) in an analytical review of the current RES and rational use of energy development status in the GCC region, give special emphasis to the business opportunities that the region offers for regional and international companies involved in this market.

Patlitzianas *et al.* (2006) have focused on the identification and assessment of sustainable energy investments in the framework of the EU-GCC cooperation. Their work is mainly based on the framework of the European Commission's programme "Synergy" that was implemented in the period 2003-2005. The authors analyze in a coherent and integrated way the constraints hampering the development of RE, to describe the relative efforts that are connected with the stated role of the RE and they

propose some useful recommendations for future development. Along the same lines, Spiess (2008) identifies some of the major political and institutional constraints within the special context of the GCC socio-cultural environment with respect to developing adaptive capacities to the vulnerabilities of climate change. The conclusions of the author's work show that the prevailing political ideology currently has little chance for the success of sustainability in the region.

Al-Badi *et al.* (2009) present a review of the assessed potential of renewable resources and practical limitations to their considerable use in the perspective of present scenarios and future projections of the national energy for Oman. Jalilvand (2012) presents polices for the successful transition of the energy supply in the Middle East and North Africa (MENA) to RE. The author discusses, from a politico-economic perspective, how RE can be promoted in the MENA region. Luomi (2009) refers to the major Abu Dhabi's alternative energy initiatives and advocates for the fact that they are geared to some of the most momentous of domestic challenges: economic diversification, job creation for the growing national population, demand-side management of energy security and transfer of technology and knowledge. Reiche (2010b) describes the key characteristics of Masdar City, analyses the drivers behind the project and identifies the main actors of its implementation as well as the obstacles to its creation and development and the policy behind Masdar City.

Nevertheless, no scientific research has been conducted so far, combining all the information regarding the status and the potential of RE deployment in the GCC region as well as the main drivers and barriers to the vast deployment of RET on a "per country" basis. In this respect, to cover the gap identified, the present study sums up the information gathered from the literature, providing a structured review of the RE status in each GCC country as well as a qualitative evaluation of the barriers and drivers to the vast announced deployment of RE projects in the region.

After briefly addressing RE potential in the region, the paper presents major existing and planned RE projects in the region. The main factors driving the RE deployment are then presented as well as the obstacles that hamper the promotion of RE projects in the GCC region. The identified barriers' and drivers' rating is presented on a "per country" basis, providing a classification which is not present in the international scientific literature. In conclusion, the paper highlights the need to establish supportive policy frameworks that more strongly support the transition to a more sustainable development path.

2. Potential for RE sources

2.1 Resource assessment efforts

The unique characteristics of RET are that they use, by definition, sustainable energies, can be implemented relatively quickly, come in modular units, support distributed generation, offer more work opportunities and have a much lower environmental impact than stock energy options, including achieving the lowest CO_2 emissions. Most are suited for co-generation, are geographically dispersed, and have a modest footprint, while some can be placed on the roofs of existing and new buildings (Holm *et al.*, 2008).

To this end, several initiatives to assess resource potential have been carried out in the GCC countries since the early 1990s. In Bahrain, a committee (led by the Electricity and Water Authority) conducted the assessment of solar and wind energy and looked at the possibility of using these resources for the production of electricity and desalinated water[1]. In Kuwait, solar thermal energy appears to be most suitable for power generation. In 2008, a study by Japan External Trade Organization was

commissioned by the Ministry of Economy, Trade and Industry of Kuwait to assess the technical, economical and operational aspects of combined-cycle power generating system using solar thermal energy. The wind characteristics of six locations have been assessed, but the results are not very encouraging (Al-Nassar *et al.*, 2005).

All the meteorological data collected by the Directorate General of Civil Aviation and Meteorology in Oman are now available in order to assist in the RET development[2]. The Sultan Qaboos University has conducted comprehensive studies to identify the highly suitable land for solar energy applications in the country using GIS and multi-criteria analysis. The Public Authority for Electricity and Water (PAEW) has also been conducting a study to assess feasibility of solar energy. If proven feasible, tendering documentation will be prepared for the Oman Power and Water Procurement Company to initiate a fair and transparent competition to build, own and operate Oman's first large solar plant.

In Qatar, the National Food Security Programme (QNFSP) launched a solar resource assessment project to be conducted by the German Aerospace Centre – Deutsches-ZentrumfürLuft und Raumfahrte (DLR) to assess the country's most favorable areas for solar energy projects. The project involves satellite based high-resolution solar resource mapping as well as ground measurements of solar radiation to attain accurate mappings for the country (*Tribune News Network*, 2011).

From 1993 to 2000, KACST and the National RE Laboratory – the USA conducted a joint project to upgrade the solar resource assessment capability of Saudi Arabia to identify high-potential areas for RE application (Alawaji, 2001; Al-Abbadi *et al.*, 2002).

In the UAE, a preliminary assessment of solar and wind energy resources within UNEP's Solar and Wind Energy Resource Assessment (SWERA) programme was launched in 2007. The assessment was sponsored by Masdar (Hoyer-Klick, 2010) as part of the MASDAR initiative and the findings of the assessment were to be made available on the SWERA web site when completed.

2.2 Solar potential

GCC countries have a high-potential in solar radiation (Saudi Arabia having the highest one), which would allow them to generate energy at relatively high efficiency. In a well-documented study by DLR, "Concentrating solar power for the Mediterranean region (MED-CSP)", it was shown that the potential for CSP in the GCC countries is several orders of magnitude above the energy demand of these countries.

Only 0.2 per cent of GCC land area (625,000 km^2) of GCC countries (2.5 million km^2) is needed to fulfill all the electricity needs of GCC citizens (60 GW or 250 TWh in 2003), assuming the efficiency of the CSP is only 20 per cent (Alnaser and Alnaser, 2011). On average, the global solar radiation – for the use of photovoltaics (PV) – is nearly 6 kWh/m^2/day and the direct solar radiation – for use of solar rough concentrator – is 6.2 kWh/m^2/day (Table I). However, high levels of dust, caused by the high occurrence of dust storms covering the panels with dust and lowering their performance, may threaten technological efficiency.

2.3 Wind potential

The GCC region has a moderate potential for wind power generation capacity. Average wind speed in the GCC countries is about 6 m/s. But the wind potential varies substantially between countries as it is shown from the recorded hours of full load of wind per year in Table II.

Saudi Arabia comes first with 1,789 h and UAE comes last with 1,176 h. According to the RES, countries with more than 1,400 h per year are considered to have economically viable wind energy utility (Alnaser and Alnaser, 2009). Greatest potential is on some of the sites on the 2,000 km coastline for offshore wind.

As shown in Tables I and II the GCC region has a good potential both in total and direct solar radiation and in wind speed. The ground based solar and wind power data are presented in Table III.

2.4 Other renewable resources

As far as other types of RE are concerned, most GCC countries do not have the natural resources to make them viable such as hydrological resources and forests. Where such resources are available, such as geothermal energy, countries will need to develop geological expertise as well as political and regulatory support for the energy source in

Countries	Global solar radiation kWh/m^2/day	Direct normal solar radiation (kWh/m^2/day)
Bahrain	6.4	6.5
Kuwait	6.2	6.5
Oman	5.1	6.2
Qatar	5.5	5.6
Saudi Arabia	7.0	6.5
United Arab Emirates	6.5	6.0

Source: Alnaser and Alnaser (2009)

Table I. Solar radiation in the GCC

Country	Wind speed (m/s)	Hours of full load of wind per year
Bahrain	5-6	1,360
Kuwait	5-5.5	1,605
Oman	4-6	1,463
Qatar	5-7	1,421
Saudi Arabia	2.5-4.5	1,789
United Arab Emirates	3.5-4.5	1,176

Source: Alnaser and Alnaser (2009)

Table II. Wind potential in the GCC

Country	Solar energy (Wh/m^2)	Solar power (W/m^2)	Wind power (W/m^2)
Bahrain	5,180	563	78
Kuwait	5,990	673	140
Oman	5,410	564	141
Qatar	5,260	565	85
Saudi Arabia	5,670	683	71
United Arab Emirates	5,078	577	57

Sources: Islam *et al.* (2009, 2010); Burashid (2009); Authority for Electricity Regulation of Oman (2008); Alnaser and Alnaser (2011)

Table III. Solar and wind powers in the GCC countries (W/m^2)

order to make it commercially viable. Finally, biomass energy is not a major source for GCC countries except for municipal waste to energy processes.

3. Research and development

The deployment of RET in the GCC is a process that will unfold over decades. R&D work in the field of RE has been conducted over the past few decades in GCC countries. Investments, both at the private and public level, have been carried out in – economically expensive – innovative RETs, indicating the intention of GCC countries to play a pioneering role in the RE sector. An overview of technology and innovation centers in the GCC is provided in Table IV: selected R&D facilities in the GCC, with several research activities and programmes illustrating the interest in RE at the R&D level in the region.

Investments in the field will need to be sustained and both manufacturing capacity and proprietary intellectual property will need to be developed. R&D institutions and centers of excellence must be further established to promote new thinking and innovation. Technology clusters which spur innovation and encourage the creation of start-up technology companies need to be further promoted.

In order to understand the challenges and drivers of RET opportunities in GCC countries, it is important to understand the innovation value chain in the RE sector from R&D to commercial deployment. In the innovation value chain adopted by Grubb (2004), the first three stages (basic R&D, applied R&D and demonstration), as applied to any RET, are considered to be "Technology Push" where the technology is created and developed. The next three stages (pre-, supported and fully commercial) are considered to be "Market Pull" where the technology has proven its commercial value. By moving RETs from the lab to the market, it is expected that the cost per unit of the technology will decrease and market penetration will increase as more investments are made to deploy RETs commercially especially when the cost per unit reaches parity with other competing fossil fuel and RETs. In order to push the technology from the laboratory to the market, government policy and programme interventions are initially high and will decrease once the technology becomes more commercially viable. In parallel, business and the financial community will become more willing to investment in the technology once it has proven its reliability and economic profits. The main challenge in the innovation value chain lies in the middle segment, the technology "Valley of Death," when taking the new technology from the laboratory to the market which means moving from government funding to private investments (Grubb, 2004). The deployment of RET is as important as the R&D stage. The adoption of RE faces myriad difficulties (Shum, 2010). Two main issues of concern are that:

(1) renewable electricity still cannot economically compete with fossil-fuel generated electricity and provides no new functionality from an end-user perspective; and

(2) the social, environmental- and even security-costs of fossil fuels are not taken into account.

Therefore, more attention is needed to understand the preferences of the private investors, mainly venture capital and private equity investors (Grubb, 2004; Bürer and Wüstenhagen, 2009).

Country	R&D facilities
Bahrain	University of Bahrain (UoB) conducting studies around solar and wind energy sources Small scale R&D projects include the design and construction of mobile solar water desalination unit Bapco launched R&D policy in the field of solar energy
Kuwait	Kuwait Institute for Scientific Research (KISR) supervised and financed research on solar energy systems and their technical feasibility for power generation, heating, cooling and water desalination Analysis conducted to evaluate the financial feasibility of photovoltaic technology (Al-Hasan, 1997) Studies carried out to assess potential of grid-connected photovoltaic systems (Abdullah *et al.*, 2002; Alsayegh *et al.*, 2009) Institutions like the Public Authority for Applied Education and Training, the Kuwait Foundation for the Advancement of Sciences (KFAS), the Kuwait Society of Engineers and Kuwait University promoted alternative energy uses, research, projects and events
Oman	Governmental agencies, the Middle East Desalination Research Centre (MEDRC), and the Sultan Qabous University (SQU) conducting active research around RES MEDRC and the Caledonian College of Engineering researched the application of solar energy in reverse osmosis (RO) water desalination The Renewable and Sustainable Energies Research Group (RASERG) was established in 2003. Its mission is to provide research, consultancy services and spread awareness through education to the industry and the community in the field of renewable and sustainable energies The Ministry of Environment and Climate Affairs, the Authority for Electricity Regulation and the Public Authority for Water and Electricity are commissioning RES feasibility studies and dedicated events and seminars
Qatar	Some research on RE sources have been conducted in Qatar since 1990s (Alnaser and Almohanadi, 1990; Hamid Marafia, 2001; Marafia and Ashour, 2003) Qatar National Research Fund (QNRF), a member of Qatar Foundation for Education, Science and Community Development Qatar Science and Technology Park (QSTP). Its mission is to support international companies, institutes and entrepreneurs to develop progressive technologies in Qatar In addition to addressing all locally relevant aspects of sustainability, ecological impact and green building design criteria, QSAS developed a standalone building energy standard to support Qatar's building energy ratings (BARWA Qatari Diar Research Institute (BQDRI), 2010)
Saudi Arabia	The Energy Research Institute (ERI) in KACST conducted two major international joint programmes that have assisted in the establishment of a series of research activities and pilot projects in Saudi Arabia Solar Energy Research American Saudi (SOLERAS) directed towards demonstration projects such as solar electricity generation and decentralized usage, water desalination and cooling systems The second major research programme is Hydrogen from Solar Energy – HYSOLAR concentrated on solar based production of hydrogen (Alawaji, 2001; Doukas *et al.*, 2006)

(*continued*)

Table IV.
Selected R&D facilities in the GCC

Country	R&D facilities
	King Faisal University in Dammam, King Abdulaziz University in Jeddah, King Fahd University of Petroleum and Minerals in Dhahran (KFUPM Dhahran) and King Saud University of Riyadh have joined KACST research programme to establish solar cooling labs
	The Center for Engineering Research, KFUPM Dhahran conducted research to investigate the potential of utilizing hybrid (wind plus diesel) energy conversion systems
	KAUST would also eventually carry out research into algae for storing CO_2 emissions
UAE	Masdar Institute of Science and Technology is a post-graduate university focused on the science and engineering of advanced RE, environmental technologies and sustainability
	UAE University conducting research on topics like the environmental sustainability assessments in the UAE buildings and the utilization of solar-hydrogen energy

Table IV.

Source: Authors' own compilation

Financiers place priority on the underlying drivers for RE strategy by policymakers at national level, with respect to visibility on market development and growth in near and medium term (Hamilton, 2011). Currently most of the investors in the GCC region are interested in the commercial side of RETs especially when the unit cost of the technology is in parity with or below other conventional energy technologies. But when the unit cost of the technology is higher than other energy technologies, such as solar power, then the technology "Valley of Death" will be the biggest challenge and the right policy and mechanism must be carefully engineered to bring such technology to full commercial status with time (Jenkins and Mansur, 2011).

4. RE projects

The commitment toward greater sustainability in the region has translated into the implementation of a number of RE projects over the past few years, as summarized in this section. All six GCC countries have either embarked on or committed to investments in RE projects. The most advanced country in the region in terms of RES project implementation is the UAE but RE has started gaining momentum in the other GCC countries.

This section provides an overview of the major RE projects in the GCC countries. Table V presents a synthesis of the most significant projects currently confirmed to be at the planning stages. As can be seen, these projects are focused on solar energy, but also extend to wind, geothermal and biomass plants. The UAE, mainly through the Abu Dhabi based Masdar Initiative, is developing a number of RE projects in both solar and wind. Among them, Shams 1, in partnership with France's Total and Spain's Abengoa Solar, is expected to be one of the world's largest CSP plant at an installed capacity of 100 MW. Dubai has recently launched Mohammed bin Rashid al-Maktoum Solar Park, with a total capacity of 1 GW, extending over 48 km^2 and estimated at $3.27 billion.

Table VI provides a synthesis of significant projects under construction or completed in the last ten years. Bahrain for instance has several interesting upcoming projects, such as a 5 MW hybrid solar and wind power plant, which is at the time of writing at

Table V.
Planned projects per GCC country

Location	Project type	Year	Capacity	Project developers	Reference
			Bahrain		
	CSP plant	Planning stage	500 MW	A private consortium	Jones *et al.* (2009)
	Wind energy plant	Planning stage			Reid (2010), Norton (2011)
	Two "hybrid" power plants for solar and wind energy	Confirmed at final stages of negotiations/tendering	5 MW each or 3-5 MW in total (accounts differ)	The Electricity and Water Authority and Gazprom	Reid (2010), Alnaser and Alnaser (2011), Norton (2011), Hashem (2011a)
	Photovoltaic power plant	Planning stage; to be operational in 2012		Tanmiyat Aloula Holdings	*Renewable Energy Focus* (2010), Aaron (2011)
			Kuwait		
AlAbdali east of Kuwait	Solar power plant	Tenders invited in late 2011	1,250 MW	Ministry of Electricity and Water and Toyota T Suchu Corporation	*The Arab Times* (2011), Hashem (2011b)
Abdaliyah	Solar component in combined-cycle gas power plant	Planning stage	60 MW (solar component only)		AlBawaba (2011), MacDonald (2011)
			Sultanate of Oman		
Adam and Manah, Al Dakhiliya region	CSP project	At tendering stage	50-200 MW	PAEW	MENASOL (2011), *Oman Daily Observer* (2011)
	Solar thermal powered oil recovery plant	Contract awarded	7 MW	GlassPoint Solar	Barkatali and Yaqub (2010)
	Solar powered desalination plant	Planning stage	6,000 litres per hour	Not confirmed	Utilities-Me (2010)
Sohar	Ethanol factory (date palm biofuel production)	Approved/planning stage	900,000 litres/day	Oman Green Energy Company	Mukrashi (2010)

(*continued*)

Table V.

Location	Project type	Year	Capacity	Project developers	Reference
			Qatar		
	Solar power plant	Planning stage	At least 100 MW	Not yet decided	Alnaser and Alnaser (2011), McGinley (2010), *The Financial Express* (2009)
			Saudi Arabia		
KAUST in Jeddah	Solar thermal panels	Confirmed/planning stage	2-4 MW	Conergy Asia-Pacific and National Solar Systems	Hope (2010), Alnaser and Alnaser (2011), KAUST (2011)
Dhahran	Solar facility on a parking lot	Contract awarded/to be completed by end 2011	10 MW	The volkach, Belectric Solarkraftwerke GmbH, and Sun & Life	Bloomberg (2011a), Energy Boom (2011), PR Newswire (2011)
			United Arab Emirates		
	Wind energy plant	Bid evaluation stage	20-30 MW	Masdar	Khan (2011), Bloomberg (2011b)
Abu Dhabi	Solar power plant	Appears this project has been delayed, as completion date was supposed to be 2009	40 MW	Masdar and Conergy AG	Reuters (2007a)
Al Ain on border with Oman	Solar PV plant (Noor 1)	Contracts awarded in December 2011/to be completed by end of 2013	100 MW	Masdar	Khan (2011), Bloomberg (2011b)
Abu Dhabi	Geothermal facility	Contracting stage	5 MW (initial drilling showed project had to be downsized)	Masdar and Reykjavik Geothermal	Khan (2011)
Sir Bani Yas Island	On-shore wind farm	Tendering process	30 MW	Masdar	Masdar Power (2011)
Dubai	Solar PV and CSP (Mohammed bin Rashid al-Maktoum Solar Park)	Announced in January 2012	1,000 MW	Implemented by the Supreme Council of Energy (SCE) and managed and operated by Dubai Electricity and Water Authority (DEWA)	*Khaleej Times* (2012)

Source: Authors' own compilation

Table VI. Completed projects and projects under implementation per GCC country

Location	Project type	Year	Capacity	Project developers	Reference
			Kuwait		
	Wind turbine	Construction started in 2011	10 MW		MacDonald (2011)
			Sultanate of Oman		
Knowledge Oasis Muscat	Photovoltaic demonstrator	Completed in 2010	12 MW/year concentrator	ABS Advanced Business Solutions, Azur Space Solar Power GmbH, and Concentrix Solar GmbH	Uckat (2011)
			Qatar		
Mesaieed municipality	Biomass plant	Completed in 2006	40 MW	Keppel Integrated Engineering and the Ministry of Municipal Affairs and Agriculture	Bloomberg database
			Saudi Arabia		
Al-Khafji City	Solar powered desalination plant	Under construction since 2010. To be completed in 2012	30,000 m^3 of water per day at the first stage	KACST and IBM Research	Dignan (2010), Alnaser and Alnaser (2011)
KAUST in Jeddah	Solar PV panels	Completed in 2010	2 MW	Conergy Asia-Pacific and National Solar Systems	Hope (2010), Alnaser and Alnaser (2011), KAUST (2011)
InBahra industrial complex Mecca	Solar field	Under construction		Vision Electro Mechanical Co.	Alnaser and Alnaser (2011), Panda (2011)
Riyadh	Solar park	Under construction	3.5 MW	Phoenix Solar AG; Naizak Global Engineering	*Oman Daily Observer* (2011), Whitmore (2011)
			United Arab Emirates		
Abu Dhabi Madinat Zayed	CSP plant (Shams 1)	Under construction (started in 2010 and will be completed by the end of 2012)	100-125 MW	Abu Dhabi Water and Electricity Authority, Masdar, Total and Abengoa Solar	Renewable Innovations (2011)
Masdar City	Solar PV park	Completed	10 MW	Masdar and Enviromena Power Systems	Khan (2011), Alnaser and Alnaser (2011), Bloomberg (2011b)

(*continued*)

Table VI.

Location	Project type	Year	Capacity	Project developers	Reference
Abu Dhabi	Solar power plant	Under construction	500 MW	Masdar and the Abu Dhabi Water and Electricity Authority	*GRC Environment Research Bulletin* (2008), Reuters (2007b)
Dubai	Solar power plant	Under construction	10-100 MW (as yet not confirmed)	Dubai Water and Electricity Authority	Goumbook (2011)
Abu Dhabi	Solar roof programme on buildings in Abu Dhabi	Under construction	500 MW	Masdar and Abu Dhabi Water and Electricity Authority	EnviTech (2011)
Ras Al Khaimah	A pilot floating solar island project	Completed and being tested to examine potential replicability of the project	1 MW	Local authorities with Neuchâtel's Center for Electronics and Microtechnology	Jones *et al.* (2009), Alnaser and Alnaser (2011), UAE Interact (2010)
Burj Khalifa	Solar power for water heating	Completed in April 2010	690 MWh of energy per annum	SOLE UAE Solar Systems	Alnaser and Alnaser (2011)
Roof of the Masdar Institute building	Solar power system	Completed	1 MW	Masdar and Sunpower	Bloomberg database

Source: Authors' own compilation

the bidding stage. Additionally, a private consortium has launched a plan to construct a 500 MW CSP facility in the country. Oman, following the publication in 2008 of a RE resource study by the Authority for Electricity Regulation, has prepared a proposal for six pilot projects to harness energy from wind and solar, of which a large-scale solar thermal plants and a 750 MW wind farm rank prominently. However, as yet none of these projects have been confirmed. Aside from these pilot projects, Oman has recently floated a tender for a CSP plant between 50 and 200 MW generating capacity.

Kuwait, although being noticeably less active than its GCC neighbors in terms of upcoming RE projects, recently publicized plans for a 1,250 MW solar power plant in Al-Abdali in east of country. A momerandum of understanding (MoU) was signed with Toyota Tsusho Corporation in 2008, and the project is now at the tendering stage. Qatar, following the winning of its bid to host the FIFA World Cup in 2022, has allocated significant funds to infrastructural development, a significant part of which is RE related. One of Qatar's notable projects is a 100 MW solar power plant. In recent years, there has also been evidence of a resurgence of interest in RE in Saudi Arabia. In April 2010, King Abdullah bin Abdulaziz issued a royal decree ordering the creation of the King Abdullah City for Atomic and RE (KACARE). The city, to be based in Riyadh, will focus on the co-ordination of national RE projects across the country, as well as capacity building and R&D needs related to renewables (Sawahel, 2010). Furthermore, a German solar project developer, BelectricSolarkraftwerke GmbH, was contracted to build a 10 MW solar facility, the largest of its kind to be built on a parking lot.

The region is also opening up to new developments across the solar value chain: from capital, through to chemicals, industries, manufacturing and different consumer market segments. There has been a noted focus on the construction of manufacturing plants for poly-silicon materials. Saudi Arabia for instance has recently announced the establishment of a world class poly-silicon factory, the first of its scale in the GCC. The project is expected to cost US$1 billion, and will start production in 2013 with a capacity of up to 7,500 tons per annum. Qatar has signed an agreement to build a poly-silicon factory with a planned capacity of 3,600 tons of high-purity poly-silicon, at an expected cost of US$500 million, at the RasLaffan Industrial City in the northeast of Qatar. UAE has similarly announced plans with MBM Holdings to build a solar grade poly-silicon plant with a total capacity of 2,500 tons per annum and is expected to start production in early 2012. Table VII provides a summary of these projects.

5. Drivers and barriers to RE adoption in the GCC

While few drivers are currently supporting the deployment of RE in the GCC, there is a strong strategic and economic case for RE based on the abundant resources in the region, the finite nature of hydrocarbon resources, the rapid development of RETs and the drive to reduce greenhouse gas emissions. In addition, heavily subsidized, rapidly growing domestic energy consumption in the GCC reduces hydrocarbons export volumes and revenues, a difficult trend to sustain in the long-run.

Even for GCC countries that are still endowed with large hydrocarbon reserves, a gradual transformation process initiated early enough may be preferable in order to save costly adjustments in the future and to preserve fossil-fuel resources for the long term (Reiche, 2010a). Several countries are already engaged in economic diversification strategies as a necessary part of ensuring their long-term development plans are achieved (The Economist Intelligence Unit, 2010)[3]. Kuwait has set significantly

Country	Project type	Year	Capacity	Project developers	Reference
Qatar					
Laffan industrial city, in the north east of Qatar	Poly-silicon production facility	Plans in final stages/ to be completed by 2011	3,000-3,500 tons/ year	Solar World AG, the Qatar Foundation, and the Qatar Development Bank	MENASOL (2011), Alnaser and Alnaser (2011), *The Financial Express* (2009)
Saudi Arabia					
Al Jubail Industrial City 2	Poly-silicon facility	To start production in 2013/ assumed under construction	3,350-7,500 metric tons per annum	Polysilicon Technology Company of Saudi Arabia, Hyundai Engineering Company, KCC Engineering and Construction Corporation	MENASOL (2011), Barkatali and Yaqub (2010), Hussain (2011)
United Arab Emirates					
Dubai	Solar grade poly-silicon plant	To start production in 2012/ assumed under construction	2,500 tons per annum	MBM Solar Holdings and ERC Private Limited Singapore	Khan (2011), AME Info (2010)

Source: Authors' own compilation

Table VII.
Planned and existing poly-silicon plants in the GCC countries

ambitious target for using RE in the Gulf region (MacDonald, 2011). Abu Dhabi, despite its vast fossil-fuel reserves, has run ahead the other GCC states with the establishment of Masdar Future Energy Company and the hosting of the International RE Agency (IRENA) which aims to promote RE in both developing and industrialized countries (Luomi, 2009). As this process continues, it is in the region's interest to invest, and develop, the industries and capabilities of the future.

This section briefly analyzes the factors that may, in time, provide further incentive for RE deployment in the region as well as the main obstacles towards the development and adoption of RE. It is important to emphasise that this case is based on long-term economic and strategic considerations. RE is not going to transform GCC economies overnight or even within a decade. However, taking the longer term perspective, it is highly likely that it will play an increasingly important role. The analysis is conducted on a "per country" basis and provides a coherent evaluation of the main drivers and barriers to the adoption of RE in the GCC following a qualitative approach.

5.1 Drivers

Despite the dominance of conventional resources in the countries of Gulf, several major factors can be registered that are considered as incentives to the vast deployment of RE in the region in the upcoming period.

Rising GCC energy demand. GCC countries are major energy consumers as a result of higher-than-average economic growth rates, huge development projects in the domestic, service and infrastructure sectors (Qader, 2009), as well as growth in industrial consumption, driven by the steel, aluminium and petrochemical industries (Hart, 2010). Domestic energy consumption has grown by almost 75 per cent since 2000, and is projected to more than double by 2020 (Kinninmont, 2010). In particular, demand for electricity (mainly natural gas-based), has increased at thrice the global average over the last few years. With consumption growing at an average of 7 per cent annually, power generating capacity has to be doubled every decade (Trade Arabia, 2011). GCC countries will require 100 GW of additional power over the next ten years, the equivalent of US$25 billion in investments. Rising GCC energy demand will put pressure on government budget and reduce hydrocarbon export potential, thereby resulting in a loss of foreign-exchange revenues (Doha Carbon and Energy Forum, 2010).

Increased commitment to reduce energy subsidies. Despite the fact that GCC states have established subsidizing mechanisms for conventional domestic energy consumption, discussions have gradually begun as of late on the reduction or removal of subsidies at least in the industrial sector (Hart, 2010). GCC countries have realized that fossil-fuel subsidies cause reduction of government revenues as a result of lower exports. Qatar increased petrol, diesel and kerosene prices by 25 per cent in January 2011, while the UAE increased gasoline prices in April and July of 2010 to the highest level in the GCC (IEA, 2011). As the price of hydrocarbons increases, the opportunity cost of consuming these resources internally (versus exporting them) escalates. It is for this reason that channeling the wealth generated by hydrocarbon exports into alternative investments (for, e.g. RE) as opposed to directing this wealth towards subsidies for domestic electricity (energy) consumption allows for huge economic gains which may not be realized otherwise (Arnold, 2010).

Depleting hydrocarbon resources. Growing global energy demand is allowing for production rates to rise sharply, resulting in a faster depletion of hydrocarbon resources. The reserve-to-production (R/P) ratio for oil reserves, an indicator of reserve sustainability if production continues at the same rate, has declined from a value of 110 in 1989, to 85 in 2009. The R/P ratio for natural gas reserves also decreased from over 368 years in 1989 to around 187 in 2009 (Al Masah, 2010). These indicators hide the large disparity between countries' resource endowments. In the case of natural gas, for example, while Saudi Arabia and Bahrain are self-sufficient, Qatar and Oman are net exporters. Oman is also expected to be net importer within a few years, and the UAE and Kuwait are already importers. Generally, dependence on hydrocarbon imports from the GCC is expected to grow due to several political factors (The Economist Intelligence Unit, 2010), thereby increasing pressure on the region's finite hydrocarbon resources.

Environmental concerns. As a result of rapid economic growth, substantial population growth, and hydrocarbon production, GCC countries are among the highest per capita emitters worldwide (Reiche, 2010a; Levitt, 2009; Raouf, 2008). According to the climate analysis indicators tool, Qatar took the lead in 2010 with 46 metric tons CO_2/capita, followed by the UAE with 27.5, Bahrain with 27.2 and Kuwait with 26.7 (World Resources Institute, 2009). The Climate Change Performance Index, which ranks 57 industrialized countries and emerging economies according to the quality of their climate policy, has ranked Saudi Arabia last (Hmaidan, 2009). The GCC has also

been classified as highly vulnerable to the negative effects of climate change (Elasha, 2010), such as rising sea levels, desertification, increased temperatures, pollution in marine and coastal areas, decreased fresh water availability and increased underground water salinity (Janardhan, 2007). Environmental concerns, though at the domestic and international level have encouraged many countries in the region to move towards more sustainable development paths. The desire to reduce carbon emissions and slow global warming is firmly on the global agenda as formalized in the Kyoto Accords and GCC nations stated their agreement by signing and ratifying it in 2005 and 2006.

Abundant solar resources. GCC countries, richly endowed with hydrocarbons, are almost equally richly endowed with renewables resources. They have the solar radiation and space to develop industrial scale concentrating solar power plants. Coincidentally, in the GCC, solar irradiance levels are very well matched to meet the midday summer demand peak (Raouf, 2008), otherwise met by the use of open-cycle turbines running on high-cost fuel. The region has exceptional solar potential, and a range of other renewable opportunities. Critically, they also have the financial and technological capacity to so enhance their RE capabilities. In fast-growing GCC cities PV panels can be integrated into buildings in cities, suburbs, country towns and villages. The region also has some wind resources and some biomass (from urban waste). GCC countries currently play a world leading role in hydrocarbon industries. There is a clear potential for the GCC region to play an equivalent leading role in RE industries. With its solar resource endowments and large desert land areas, the GCC cannot only meet its domestic energy demand from renewable resources, it could potentially become a major exporter of energy derived from renewable resources.

Regulatory framework. As the shift to greater sustainability accelerates, GCC countries can chose RE as an opportunity to create new industries and new sources of national income. Some RE targets have been announced, as a result of the ratification of the Kyoto Protocol, recently: Abu Dhabi in the UAE has a 7 per cent target for renewable electricity generation by 2020; Bahrain and Kuwait have set 5 and 10 per cent targets, respectively, by 2020 and Dubai has set a target to meet 1 per cent of electricity demand with solar power by 2020 and 5 per cent by 2030; and Saudi Arabia is examining the feasibility of a 10 per cent target. Also, KAHRAMAA in Qatar has recently announced a 10 per cent RE target in its electricity mix by 2030 (Table VIII).

Regarding regulation, Oman, for example, is in the process of developing policy instruments to support the implementation of RE projects. Saudi Arabia is in the

	Target (%)	Year
Bahrain	5	2020
Kuwait	10	2020
Oman		
Qatar	10	2030
Saudi Arabia	10	2030
UAE		
Abu Dhabi	7	2020
Dubai	5	2030

Table VIII.
RE targets per GCC state

Source: Authors' own compilation

process of approving a regulatory framework for investment in RE which clarify the conditions for government funding of the RE sector. The Saudi Electricity and Cogeneration Authority (ECRA) has also suggested for auctions to take place for power produced from renewable sources on a feed-in-tariff model (Shamseddine, 2010), while Abu Dhabi is currently finalizing discussion on a FiT for solar power and Dubai has appointed the Regulation & Supervision Bureau to regulate the RE policies set by the Dubai Supreme Council of Energy. In addition, the region has witnessed the development of industry associations such as ESIA in the UAE and Saudi Arabia Solar Industries Association, serving as a platform defining solar project specifications, enabling fair competition among the different players and pushing for the development of the solar industry in the region. They aim to assist policymakers on matters related to solar policies, standards and product certifications by publishing white-papers and research reports. They also organize conferences, lectures and workshops that contribute to knowledge management and raising awareness in the region.

Albeit not sufficient, the recent interest and commitment to RE (as illustrated by the RE projects discussed in Section 4) has supported initial steps in regulations, policies and incentives.

Table IX presents a "per country" rating of the key drivers to the deployment of RE in the GCC region based on a qualitative analysis.

5.2 Barriers

Despite the fact that the GCC states seem to have initiated the implementation of RE projects, the effort to the adoption and development of RE in the region is hampered by several obstacles that can be categorised into three categories (Patlitzianas *et al.*, 2006).

The first identified category encompasses market and technological barriers, including the insufficient awareness/experience in the social and rural sector in most of the states, the absence of country assistance in RE market strategies as well as the intermittent nature of RES; power from sources such as solar and wind cannot provide the same level of uninterruptible dispatch as power from conventional fuels.

The second category concerns policy framework and legislation barriers (Doukas *et al.*, 2008). The GCC region is characterized by the absence of well organized policies and strategies as well as the lack of a legal policy framework for the promotion of RE; As yet, none of the GCC countries has officially implemented a consistent policy

	GCC countries					
Drivers	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	United Arab Emirates
Rising GCC energy demand	✓✓✓	✓✓	✓✓✓	✓✓✓✓	✓✓	✓✓✓
High cost of subsidizing domestic energy consumption	✓✓	✓✓✓✓	✓✓	✓✓✓	✓✓✓✓	✓✓✓
Depleting hydrocarbon resources	✓✓	✓✓✓	✓✓✓	✓	✓✓	✓✓✓
Environmental concerns	✓✓	✓✓	✓	✓✓✓	✓	✓✓
Abundant solar resources	✓✓✓	✓✓✓	✓✓	✓	✓✓✓	✓✓
Regulatory framework	✓✓	✓✓	✓	✓	✓✓	✓✓

Source: Authors' own compilation

Table IX.
"Per country" rating of the drivers to the adoption of RE in the GCC region

framework to attract investors and developers in the RE sector. Despite the efforts mentioned above in terms of policy legislations, in favor of the adoption of RET, the region still lacks a regulatory framework that encourages RE investing. For example, in Saudi Arabia, the major identified barriers to the exploitation of geothermal energy are not technically related barriers, but rather the lack of political support, the lack of incentives to encourage private sector participation, as well as the lack of awareness of appropriate stakeholders of the opportunities available (Taleb, 2009).

Should governments decide to develop the potential for RE, comprehensive and long-term strategies would need to be implemented. To overcome existing structural weaknesses, changes in the regulatory framework will be necessary. Also, the creation of entities devoted to the development of policies and regulations and follow up on their implementation will be a necessary stepping stone (Patlitzianas *et al.*, 2006).

Two other remarkable observations, classified as policy framework and legislation barriers are the fact that groups that benefit from the dependence on conventional fuels seem to try to delay the establishment of a policy framework relevant to the promotion of RE in the region as well as the considerable difficulty of RETs in the accessibility to the transmission system.

The third category is related to the financial barriers and concerns the high capitals required for the implementation of RE projects, the non-existence of a subsidizing mechanism for power from RE sources with the simultaneous presence of a similar subsidizing mechanism for conventional fuels and the exclusion of environmental issues in price formation. The high cost of subsidizing domestic energy consumption, which usually take the form of state-imposed tariffs and tax-free regulations (Qader, 2009), allow for electricity prices that do not reflect the depleting nature of resources or the associated environmental costs. In the UAE, consumers are charged tariffs of about 20-60 per cent of production costs (Mezher *et al.*, 2011). Another example is Kuwait, where consumers pay only 2 fils/KWh compared to the production cost of more than 35 fils/kWh (MacDonald, 2011). Except for the UAE and Oman, GCC countries retail prices of gasoline and diesel are below the world market price for crude oil (Reiche, 2010a).

In Figure 1, shown IEA's estimates for the average subsidization rates for domestic conventional fuels in several countries, Kuwait, Saudi Arabia, Qatar and UAE are ranked particularly high. Correspondingly, in Figure 2, shown a cross-country

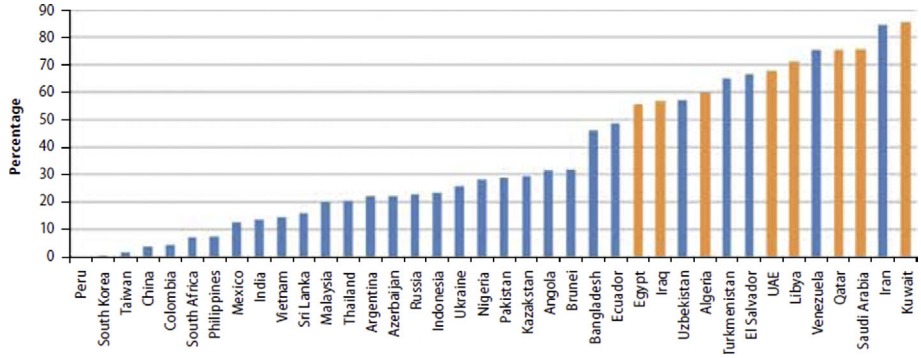
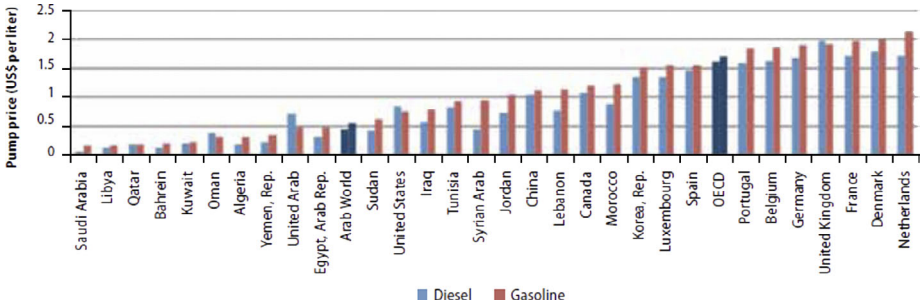


Figure 1.
Average subsidization rates for domestic fuels in selected countries for 2010

Sources: IEA, OPEC, OECD, and The World Bank (2010); Fattouh and El-Katiri (2012)



Sources: The World Bank (2010); Fattouh and El-Katiri (2012)

Figure 2.
Average retail prices for gasoline and diesel in selected countries in $/litre

comparison of average retail prices for gasoline and diesel, prices for fuel appear to be very low in the GCC countries.

It is noteworthy that there are strong political and social reasons behind the current level of subsidies (Arnold, 2010), with many considering cheap energy a right of citizenship and a way by which wealth is redistributed (The Economist Intelligence Unit, 2010).

At the same time, no subsidy mechanism exists in the GCC states for RETs whose production cost is much higher than that of conventional power. In this framework, renewable electricity still cannot economically compete fossil-fuel generated electricity and provides no new functionality from the end-user point of view (Shum, 2010). In Abu Dhabi, however, projects have moved forward through the competitive bidding process or power purchase agreements (PPAs), similarly to how it negotiates conventional power plants. The Shams 1 100 MW CSP plant has been negotiated following the PPA model with the government maintaining 60 per cent ownership of the project and the remaining 40 per cent controlled by the project developers. The Noor 1 100 MW Solar PV project will be awarded in the same manner as will any future RE plants. In order to make the renewable power from Shams 1 affordable, the government will be subsidizing it through a "Green Payment" although it is not confirmed whether or not this will be the case for each renewable project.

Table X provides the "per country" rating of the barriers identified above.

Bahrain, with no registered completed RE projects at the time of writing appears to slowly initiate the integration of RE. Several interesting projects are planned to be implemented in the coming years. The absence of an appropriate policy framework

GCC country	Categories Market and technological	Policy framework and legislation	Financial
Bahrain	✓✓✓	✓✓✓	✓✓
Kuwait	✓✓✓✓	✓✓	✓✓✓
Oman	✓✓	✓✓✓	✓✓✓
Qatar	✓✓✓✓	✓✓	✓✓✓
Saudi Arabia	✓	✓	✓✓✓
United Arab Emirates	✓	✓	✓✓

Source: Authors' own compilation

Table X.
"Per country" rating of the barriers to the adoption of RE in the GCC region

though, combined with the unfavorable pricing mechanism for RE power consumption pose significant braking in the vast deployment of RE in the country. Kuwait, with two solar power related planned projects and one wind turbine currently under implementation, proceeds tentatively in the adoption of RE. A factor with significant impact on the interception of RE deployment in the country is the subsidizing mechanism that privileges conventional fuels. Oman and Qatar are also assessed to address significant barriers to the adoption of RE. The barriers in these countries concern all the three categories mentioned (market and technological, policy framework and legislation and financial). However, some tentative activity has initiated with several upcoming projects in the sector of solar and biofuels being at the stage of tendering or planning.

Saudi Arabia and UAE are evaluated to be in a better position concerning the existence of factors hampering the vast deployment of RE. These countries' established research centers have conducted a series of research activities and pilot projects to investigate and exploit the RE potential in the region. These activities are related to solar electricity, decentralized usage, water desalination and cooling systems as well as to the potential of utilizing hybrid energy conversion systems and solar-hydrogen energy. In UAE, Masdar Institute, focusing on advanced RE, offers important dissemination activities towards the promotion of RE in the social sector. The major barrier for Saudi Arabia and UAE to hasten the adoption of RE is the absence of a clear legal framework, outbidding RE vast deployment.

Taking the above assessment into consideration, neither resource availability nor techno-economics is evidenced as the major constraint to the vast adoption of RET, but a limiting mindset focused on the supply-side, partial energy costing, low (indirectly subsidized) energy prices and short-term thinking favoring low initial costs.

In order to overcome the barriers and promote the establishment of RETs, GCC governments should focus both on short-term and medium/long-term axes if they chose to further deploy RE. In the short-term, it is recommended that GCC countries diversify experiences affecting other mature technologies that already have a sizeable market potential, such as desalination of water and solar cooling, while in the medium/long term, it is proposed that a global RE strategy should be set and implemented, including a stable and long-term policy framework, and financial incentives and standardization (Taoumi, 2010). At the same time, GCC countries may want to consider a more drastic reduction of conventional fuels subsidies in order to provide RE with a level playing field.

6. Conclusion

The GCC countries have recently shown a keen interest in embarking on a more sustainable development path, in which the RE sector is expected to play a significant part. Several R&D institutions have been set up, various research programmes initiated, and initial steps taken towards the creation of technology clusters focused on RETs to spur innovative processes in the GCC. Several initiatives to assess RE resource potential for large-scale deployment are also being actively undertaken. Numerous RE projects have also been launched and many more are in the planning stages, demonstrating the commitment of GCC states to tap into their RE resources. However, investors in the GCC region have concentrated efforts on the commercial side of RE, particularly when the unit cost of the technology is in parity with or below other conventional energy technologies. Despite these positive developments, at the time of writing, there

is a number of drivers to the adoption of RE in the GCC. One of these has been environmental concern over the harmful effects of climate change in the region, as well as the negative portrayal of GCC countries in the international community as a result of being among the major per capita emitters worldwide. There has also been a palpable drive to achieve greater economic diversification as part of the GCC's long-term development plans, some of which are already underway. Another driver has been the realization of the GCC's rich RE resource endowment, particularly solar energy, as well as the expansive, largely uninhabited areas available for the development of industrial scale power plants.

However, it is evident that current trends are not sustainable, and with time, will increase the pressure to move towards greater RE deployment in the region. These include the mounting global energy demand for hydrocarbon production, the relatively high level of energy subsidies for domestic energy consumption, and the finite nature of hydrocarbon resources in the region. Additionally, as a consequence of high economic and population growth rates, domestic energy demand and electricity consumption are expanding rapidly. Nevertheless, enabling government policy and regulatory frameworks will still need to be designed and implemented, in order to create the conditions needed to attract investors and developers for RE to become a significant part of the energy mix.

Based on the above, the GCC countries face the major short- and long-term challenge of diversifying their existing conventional fuel energy based economy into a new one, based on alternative fuels and mainly RE. To effectively deal with such a makeover, GCC nations should move according to the drivers and promote all the necessary actions to sustain their pioneering role in energy and electricity production with the arrival of the new RET era. Such actions should be primarily translated into the promotion of favorable policy frameworks for the optimal integration of RETs. An effective action framework requires a long-term commitment as well as measures that are long, loud and legal. Towards this end, governments should provide incentives for R&D institutions to promote knowledge and innovation and acquire expertise in the sector of RET. A proper RET policy framework should ensure that private energy investments are moving towards a diversified RET direction. It is also of significant importance that the pricing mechanism of conventional fuels should be consolidated in order to take into consideration the environmental impact of excessive fossil-fuels' consumption. As a final important point, GCC nations should support end-use of RET both by promoting advertising campaigns – in order to edify environmental awareness – and by providing incentives for consumers to adopt RET for residential, commercial and industrial use.

Notes

1. The Electricity and Water Authority, Ministry of Industry and Commerce, National Oil and Gas Authority, Bahrain Petroleum Company (BAPCO), Alba, University of Bahrain and the Public Commission for the Protection of Marine Resources, Environment and Wildlife.
2. This includes air temperature, dew point temperature, relative humidity, atmospheric pressure, surface wind speed/direction, solar radiation, sunshine duration, ground surface temperature, etc.
3. See Abu Dhabi and Qatar 2030 Vision (The Government of Abu Dhabi, 2008; General Secretariat for Development Planning, 2008).

References

Aaron (2011), "Bahrain to build $200 m solar PV plant", *Global Energy Magazine*, available at: www.easy-solar-quote.co.uk/global-energy-magazine-%C2%BB-bahrain-to-build-200 m-solar-pv-plant/ (accessed 29 December 2011).

Abdullah, A.H., Ghoneim, A.A. and Al-Hasan, A.Y. (2002), "Assessment of grid-connected photovoltaic systems in the Kuwaiti climate", *Renewable Energy*, Vol. 26 No. 2, pp. 189-99.

Al-Abbadi, N.M., Alawaji, S.H., Bin Mahfoodh, M.Y., Myers, D.R., Wilcox, S. and Anderberg, M. (2002), "Saudi Arabian solar radiation network operation data collection and quality assessment", *Renewable Energy*, Vol. 25 No. 2, pp. 219-34.

Alawaji, S.H. (2000), "Renewable energy research, development and applications in Saudi Arabia", *World Renewable Energy Congress 6, Brighton, July*, pp. 1665-8.

Alawaji, S.H. (2001), "Evaluation of solar energy research and its applications in Saudi Arabia – 20 years of experience", *Renewable and Sustainable Energy Reviews*, Vol. 5 No. 1, pp. 59-77.

Al-Badi, A.H., Malik, A. and Gastli, A. (2009), "Assessment of renewable energy resources potential in Oman and identification of barrier to their significant utilization", *Renewable and Sustainable Energy Reviews*, Vol. 13 No. 9, pp. 2734-9.

AlBawaba (2011), "Kuwait sets huge renewable energy goal", available at: www.albawaba.com/kuwait-sets-huge-renewable-energy-goal-398699 (accessed 19 December 2011).

Al-Hasan, A.Y. (1997), "Electricity generation cost between proposed photovoltaic station and conventional units in Kuwait", *Renewable Energy*, Vol. 12 No. 3, pp. 291-301.

Al Masah (2010), *Unlocking the Potential of Alternative Energy in MENA*, Al Masah Capital Limited, Dubai.

Alnaser, N.W., Flanagan, R. and Alnaser, W.E. (2008), "Potential of making – over to sustainable buildings in the Kingdom of Bahrain", *Energy and Buildings*, Vol. 40 No. 7, pp. 1304-23.

Alnaser, W.E. and Almohanadi, A.H. (1990), "Wind and solar energy in Qatar", *Energy*, Vol. 15 No. 10, pp. 931-4.

Alnaser, W.E. and Alnaser, N.W. (2009), "Solar and wind energy potential in GCC countries and some related projects", *Journal of Renewable and Sustainable Energy*, Vol. 1 No. 2, pp. 1-28.

Alnaser, W.E. and Alnaser, N.W. (2011), "The status of renewable energy in the GCC countries", *Renewable and Sustainable Energy Reviews*, Vol. 15, pp. 3074-98.

Alnaser, W.E., Trieb, F. and Knies, G. (2007), "The potential of concentrated solar power (CSP) 1365 in the GCC countries", in Yogi Goswami, D. and Zhao, Y. (Eds), *Proceedings of ISES World Congress 200: Solar Energy and Human Settlement*, Springer, Berlin, pp. 1843-8.

Al-Nassar, W., Alhajraf, S., Al-Enizi, A. and Al-Awadhi, L. (2005), "Potential wind power generation in the State of Kuwait", *Renewable Energy*, Vol. 30 No. 14, pp. 2149-61.

Alsayegh, O., Alhajraf, S. and Albusairi, H. (2009), "Managing grid-connected renewable energy sources systems", *Global Conference on Renewables and Energy Efficiency for Desert Regions – GCREEDER 2009*, pp. 1690-3.

Alusi, A., Eccles, R.G., Edmondson, A.C. and Zuzul, T. (2011), "Sustainable cities: oxymoron or the shape of the future?", Working Paper 11-062, Harvard Business School, Boston, MA.

AME Info (2010), "Solar polysilicon plant in Dubai to complement UAE's existing solar activities", available at: www.ameinfo.com/239163.html (accessed 29 December 2011).

(*The*) *Arab Times* (2011), "Solar power plant eyed – $650 million cost", available at: www.arabtimesonline.com/NewsDetails/tabid/96/smid/414/ArticleID/155515/reftab/73/Default.aspx (accessed 20 December 2011).

Arnold, T. (2010), "Fuel subsidies take toll on GCC", *The National*, available at: www.thenational.ae/business/banking/fuel-subsidies-take-toll-on-gcc (accessed 29 December 2011).

Authority for Electricity Regulation of Oman (2008), "Study on renewable energy resources", final report.

Barkatali, S. and Yaqub, Y. (2010), "Renewables spread to the MENA region", *Infrastructure Journal Supporting Infrastructure Investment*, October.

BARWA Qatari Diar Research Institute (BQDRI) (2010), "Qatar sustainability assessment system (QSAS)", available at: www.bqdri.org/index.php?page=qsas (accessed 28 December 2011).

Bloomberg (2011a), "Belectric wins contract for largest Saudi solar plant", ArabianBusiness.com, available at: www.arabianbusiness.com/belectric-wins-contract-for-largest-saudi-solar-plant-392075.html (accessed 26 November 2011).

Bloomberg (2011b), "Masdar plans wind turbine project, new solar plant", *Arabian Business*, available at: www.arabianbusiness.com/masdar-plans-wind-turbine-project-new-solar-plant–372640.html (accessed 26 November 2011).

Burashid, K.A. (2009), *Overview of Solar and Wind Energy in the Kingdom of Bahrain & The States of the Gulf Cooperation Council*, Kingdom of Bahrain, Bahrain.

Bürer, M.J. and Wüstenhagen, R. (2009), "Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors", *Energy Policy*, Vol. 37 No. 12, pp. 4997-5006.

Carley, S. (2009), "State renewable energy electricity policies: an empirical evaluation of effectiveness", *Energy Policy*, Vol. 37, pp. 3071-81.

Dignan, L. (2010), "IBM, Saudi Arabia research center eye solar-powered desalination plant", *Smart Planet*, available at: www.smartplanet.com/blog/smart-takes/ibm-saudi-arabia-research-center-eye-solar-powered-desalination-plant/5795 (accessed 20 December 2011).

Doha Carbon and Energy Forum (2010), "Alternative energy", Briefing Paper on Energy Security Initiative of Doha Carbon and Energy Forum, available at: www.dcef-qatar.org/app/media/3623 (accessed 30 December 2011).

Doukas, H., Patlizianas, K.D., Kagiannas, A.G. and Psarras, J. (2006), "Renewable energy sources and rational of the energy development in the countries of GCC: myth or reality", *Renewable Energy*, Vol. 31 No. 6, pp. 755-70.

Doukas, H., Patlitzianas, K.D., Kagiannas, A.G. and Psarras, J. (2008), "Energy policy making: an old concept or a modern challenge?", *Energy Sources, Part B: Economics, Planning, and Policy Journal*, Vol. 3 No. 4, pp. 362-71.

Doukas, H., Makarouni, I., Karakosta, C., Marinakis, V. and Psarras, J. (2012), "EU-GCC clean energy cooperation: from concept to action", in Tortora, M. (Ed.), *Sustainable Systems and Energy Management at the Regional Level: Comparative Approaches*, Chapter 15, University of Florence, Florence, pp. 288-308.

(The) Economist Intelligence Unit (2010), "The GCC in 2020: resources for the future", *The Economist*, available at: http://graphics.eiu.com/1C6CBA75-5B6E-4D44-9AD0-9932EB812198/FinalDownload/DownloadId-5C9F654D8D3BB8FD3F9963FD2EB3FCD0/1C6CBA75-5B6E-4D44-9AD0-9932EB812198/upload/eb/GCC_in_2020_Resources_WEB.pdf (accessed 20 December 2011).

Elasha, B.O. (2010), "Mapping of climate change threats and human development impacts in the Arab region", United Nations Development Programme, Regional Bureau for Arab States.

El-Husseini, I., Fayad, W., El Sayed, T. and Zywietz, D. (2009), *A New Source of Power – The Potential for Renewable Energy in the MENA Region*, Booz & Co., New York, NY.

Energy Boom (2011), *Oil Giant Commissions 10 MW Solar Parking Lot*, Energy Boom, available at: www.energyboom.com/solar/oil-giant-commisions-10-mw-solar-parking-lot (accessed 26 November 2011).

EnviTech (2011), *EnviTech Solar Mosque Project*, Envi Tech Middle East, available at: www.envitech.ae/projects/solar-mosque (accessed 20 December 2011).

Fattouh, B. and El-Katiri, L. (2012), "Energy subsidies in the Arab World", Arab Human Development Report, UNDP, Geneva.

(*The*) *Financial Express* (2009), "Qatar to build $500 m solar power plant", *The Financial Express*, available at: www.financialexpress.com/news/qatar-to-build-500-m-solar-powerplant/437936/ (accessed 20 December 2011).

Flamos, A. (2010), "The clean development mechanism – catalyst for wide spread deployment of renewable energy technologies? or misnomer?", *International Journal, Environment, Development and Sustainability*, Vol. 12 No. 1, pp. 89-102.

Flamos, A., Roupas, Ch. and Psarras, J. (2012), "GCC economies diversification: still a myth?", *International Scientific Journal: Energy Sources, Part B: Economics, Planning and Policy* (in press).

Flamos, A., Ergazakis, K., Moissis, D., Doukas, H. and Psarras, J. (2010), "The challenge of a EU-GCC clean energy network", *International Journal of Global Energy Issues*, Vol. 33 Nos 3/4, pp. 176-88.

General Secretariat for Development Planning (2008), *Qatar National Vision 2030*, available at: www.gsdp.gov.qa/portal/page/portal/GSDP_Vision_Root/GSDP_EN/What%20We%20Do/QNV_2030 (accessed 21 December 2011).

Goumbook (2011), "Dubai plans big solar plant", Goumbook Your Green Connection, available at: www.goumbook.com/tag/solar-plant/ (accessed 26 November 2011).

(The) Government of Abu Dhabi (2008), *Abu Dhabi Economic Vision 2030*, available at: www.masdarcity.ae/userfiles/files/economic-vision-2030-executive-summary-mandate2.pdf (accessed 22 December 2011).

GRC Environment Research Bulletin (2008), Issue No. 4, February, available at: www.grc.ae/data/contents/uploads/environment_7412.pdf (accessed 29 December 2011).

Grubb, M. (2004), "Technology innovation and climate change policy: an overview of issues and options", *Keio Economic Studies*, Vol. 41 No. 2, pp. 103-32.

Hamilton, K. (2011), "Investing in renewable energy in the MENA region: financier perspectives", EEDP Working Paper, Chatham House, London.

Hart, K. (2010), "GCC gas shortage to force removal of subsidies", *Emirates 24/7*, available at: www.emirates247.com/business/energy/gcc-gas-shortage-to-force-removal-of-subsidies-2010-09-05-1.287606

Hashem, H. (2011a), "Bahrain: is this market ripe for solar?", *PV Insider*, available at: http://news.pv-insider.com/thin-film-pv/bahrain-market-ripe-solar (accessed 20 December 2011).

Hashem, H. (2011b), "Kuwait's solar energy market: challenges worth solving?", *PV Insider*, available at: http://news.pv-insider.com/thin-film-pv/kuwait%E2%80%99s-solar-energy-market-challenges-worth-solving (accessed 29 December 2011).

Hepbasli, A. and Alsuhaibani, Z. (2011), "A key review on present status and future directions of solar energy studies and applications in Saudi Arabia", *Renewable and Sustainable Energy Reviews*, Vol. 15 No. 9, pp. 5021-50.

Hertog, S. and Luciani, G. (2009), "Energy and sustainability policies in the GCC", Kuwait Programme on Development, Governance and Globalisation in the Gulf States.

Hmaidan, W. (2009), "The role of the Arab World in the post-2012 climate negotiations", Foreign Policy Digest.

Holm, D., Banks, D., Schäffler, J., Worthington, R. and Afrane-Okese, Y. (2008), "Potential of renewable energy to contribute to national electricity emergency response and sustainable development", Scoping the Impact of Renewable Energy in South Africa, Version 8, 18 July, August.

Hope, G. (2010), "KAUST boasts Saudi's largest solar installation", *ConstructionWeekOnline*, available at: www.constructionweekonline.com/article-8405-kaust-boasts-saudis-largest-solar-installation/ (accessed 20 December 2011).

Hoyer-Klick, C. (2010), "Renewable energy discussion group", available at: www.eugcc-cleanergy.net, www.eugcc-cleanergy.net/LinkClick.aspx?fileticket=uaQjj3dq1MM%3D&tabid=167&mid=643 (accessed 26 December 2011).

Hussain, E. (2011), "Saudi Arabia to get region's 1st Polysilicon Plant", *Arabian Oil and Gas*, available at: www.arabianoilandgas.com/article-8640-saudi-arabia-to-get-regions-1st-polysilicon-plant/ (accessed 28 December 2011).

IEA (2011), "Database", available at: www.iea.org/weo/files/ann_plans_phaseout.pdf (accessed 8 December 2011).

IEA, OPEC, OECD, and The World Bank (2010), "Analysis of the scope of energy subsidies and suggestions for the G-20 initiative", Joint Report Prepared for Submission to the G-20 Summit Meeting Toronto, June.

Islam, M.D., Alili, A.A., Kubo, I. and Ohadi, M. (2010), "Measurement of solar-energy (direct beam radiation) in Abu Dhabi, UAE", *Renewable Energy*, Vol. 35 No. 2, pp. 515-19.

Islam, M.D., Kubo, I., Ohadi, M. and Alili, A.A. (2009), "Measurement of solar-energy (direct beam radiation) in Abu Dhabi, UAE", *Applied Energy*, Vol. 86 No. 4, pp. 511-15.

Jalilvand, D.R. (2012), *Renewable Energy for the Middle East and North Africa. Policies for a Successful Transition*, Friedrich Ebert Stieftung, Bonn, February.

Janardhan, M. (2007), "Climate change-MIDEAST: producers and victims of fossil fuels", *IPS*, 13 December.

Jenkins, J. and Mansur, S. (2011), *Bridging the Clean Energy Valleys of Death*, Breakthrough Institute, Oakland, CA.

Johnstone, N., Hascic, I. and Popp, D. (2008), "Renewable energy policies and technological innovation: evidence based on patent counts", *Environmental and Resource Economics*, Vol. 45, pp. 133-55.

Jones, L., Molan, N. and Vison & Elkins (2009), "Energy and renewables", Chapter 27, available at: www.velaw.com/uploadedFiles/VEsite/Resources/GCCCHAPTER27.pdf (accessed 20 December 2011).

KAUST (2011), "The university: sustainable development", available at: http://inauguration.kaust.edu.sa/university/sustainable-development.aspx (accessed 29 December 2011).

(*The*) *Khaleej Times* (2012), "Dubai launches solar park", *The Khaleej Times*, 9 January.

Khan, M. (2011), "Global renewable/alternative energy trends and associates policies for the UAE: a research study", *OverseasPakistaniFriends*, available at: www.opfblog.com/12340/global-renewablealternative-energy-trends-and-associates-policies-for-the-uae-a-research-study/ (accessed 29 December 2011).

Kinninmont, J. (2010), *The GCC in 2020: Resources for the Future*, The Economist Intelligence Unit, London, p. 7.

Levitt, T. (2009), "Carbon emissions: the world in 2010", *The Ecologist*, available at: www.theecologist.org/News/news_analysis/383922/carbon_emissions_the_world_in_2010.html (accessed 20 December 2011).

Luomi, M. (2009), "Abu Dhabi's alternative energy initiatives: seizing climate change opportunities", *Middle East Policy*, Vol. 16 No. 4, pp. 102-17.

McGinley (2010), "Qatar plans $1 bn solar power project", available at: www.arabianbusiness.com/578132-qatar-plan-1bn-solar-powerproject (accessed 26 November 2011).

MacDonald, F. (2011), "Kuwait sets biggest gulf clean-energy goal to boost oil exports", *Bloomberg*, available at: www.bloomberg.com/news/2011-10-25/kuwait-sets-biggest-gulf-renewable-energy-goal-to-free-crude-for-export.html (accessed 29 December 2011).

Marafia, H.A. (2001), "Feasibility study of photovoltaic technology in Qatar", *Renewable Energy*, Vol. 24 Nos 3/4, pp. 565-7.

Marafia, H.A. and Ashour, H.A. (2003), "Economics of off-shore/on-shore wind energy systems in Qatar", *Renewable Energy*, Vol. 28 No. 12, pp. 1953-63.

Marques, A.C. and Fuinhas, J.F. (2011), "Drivers promoting renewable energy: a dynamic panel approach", *Renewable and Sustainable Energy Reviews*, Vol. 15, pp. 1601-8.

Masdar Power (2011), "Sir Bani Yas wind farm", *Masdar Power Factsheet*, Masdar Power.

MENASOL (2011), "North Africa and Middle East solar country profiles", El Jadida (Casablanca), Morocco, 4-5 May.

Mezher, T., Dawelbait, G. and Abbas, Z. (2012), "Renewable energy policy options for Abu Dhabi: drivers and barriers", *Energy Policy*, Vol. 42, pp. 315-28.

Mukrashi, F. (2010), "Soon, fuel out of date palms", *Times of Oman*, available at: www.timesofoman.com/innercat.asp?detail=37605 (accessed 20 December 2011).

Norton, R. (2011), *Renewable Energy in Bahrain*, available at: www.nortonrose.com/knowledge/publications/33679/renewable-energy-in-bahrain (accessed 20 December 2011).

Oman Daily Observer (2011), "Oman's phoenix solar to build solar park for Saudi Aramco", available at: www.zawya.com/Story.cfm/sidZAWYA20110216042434/Oman's%20Phoenix%20Solar%20to%20build%20solar%20park%20for%20Saudi%20Aramco (accessed 20 December 2011).

Panda, B. (2011), "Construction products launches solar energy project", *Arabian Business*, available at: www.arabianbusiness.com/construction-products-launches-solar-energy-project-342170.html (accessed 26 November 2011).

Patlitzianas, K.D., Doukas, H. and Psarras, J. (2006), "Enhancing renewable energy in the Arab States of the Gulf: constraints & efforts", *Energy Policy*, Vol. 34 No. 18, pp. 3719-26.

PR Newswire (2011), "World largest solar parking project in the Kingdom of Saudi Arabia, at HQ of Saudi Arabian Oil Company (Saudi Aramco)", available at: www.prnewswire.com/news-releases/world-largest-solar-parking-project-in-the-kingdom-of-saudi-arabia-at-hq-of-saudi-arabian-oil-company-saudi-aramco-119071674.html (accessed 26 November 2011).

Qader, M. (2009), "Electricity consumption and GHG emissions in GCC countries", *Energies*, pp. 1201-13, available at: www.mdpi.com/1996-1073/2/4/1201/pdf (accessed 29 December 2011).

Raouf, M.A. (2008), "Climate change threats, opportunities, and the GCC countries", Policy Brief, The Middle East Institute.

Reiche, D. (2010a), *Energy Policies of Gulf Cooperation Council (GCC) Countries – Possibilities and Limitations of Ecological Modernization in Rentier States*, Elsevier, Amsterdam, pp. 2395-403.

Reiche, D. (2010b), "Renewable energy policies in the gulf countries: a case study of the carbon-neutral 'MasdarCity' in Abu Dhabi", *Energy Policy*, Vol. 38 No. 1, pp. 378-82.

Reid, A. (2010), "Wind energy plant is planned for Bahrain", *Gulf Jobs Market News*, available at: http://news.gulfjobsmarket.com/wind-energy-plant-is-planned-for-bahrain-7861973-news (accessed 26 November 2011).

Renewable Energy Focus (2010), "Tanmiyat plans US$200 m solar PV in Bahrain", available at: www.renewableenergyfocus.com/view/11972/tanmiyat-plans-us200 m-solar-pv-in-bahrain/ (accessed 26 November 2011).

Renewable Innovations (2011), "MENA taps its green reserves", Renewable Innovations, available at: http://renewableinnovations.co.uk/news.php (accessed 20 December 2011).

Reuters (2007a), "Abu Dhabi, Germany's Conergy sign solar power deal", available at: http://uk.reuters.com/article/2007/07/02/uae-solar idUKL0232136520070702 (accessed 26 November 2011).

Reuters (2007b), "Abu Dhabi to build $350 m solar power plant", available at: www.arabianbusiness.com/abu-dhabi-build-350 m-solar-power-plant-126866.html (accessed 26 November 2011).

Sawahel, W. (2010), "Saudi Arabia creates city for nuclear and renewable energy", SciDev Net, available at: www.scidev.net/en/news/saudi-arabia-creates-city-for-nuclear-and-renewable-energy.html (accessed 26 November 2011).

Shamseddine, R. (2010), "Saudi Arabia hopes for 'renewables' regulations in 2011", *Arabian Business*, available at: www.arabianbusiness.com/saudi-arabia-hopes-for-renewables-regulations-in-2011-270214.html (accessed 20 December 2011).

Shum, K.L. (2010), *The Innovation Value-Added Chain for Renewable Energy Deployment*, Industry Outlook.

Sovacool, B. (2009), "Rejecting renewables: the socio-technical impediments to renewable electricity in the United States", *Energy Policy*, Vol. 37, pp. 4500-13.

Spiess, A. (2008), "Developing adaptive capacity for responding to environmental change in the Arab Gulf states: uncertainties to linking ecosystem conservation, sustainable development and society in authoritarian rentier economies", *Global and Planetary Change*, Vol. 64, pp. 244-52.

Taleb, H. (2009), *Barriers Hindering the Utilisation of Geothermal Resources in Saudi Arabia*, Elsevier, Amsterdam, pp. 183-8.

Taoumi (2010), "Renewable energy in GCC countries: assets and challenges", paper presented at 1st Discussion Group Meeting, Cleanenergy.Net.

Trade Arabia (2011), "Renewables can meet GCC power demand", available at: www.gulfbase.com/News/renewables–can-meet-gcc-power-demand-/192837?pageID=157

Tribune News Network (2011), "QNFSP awards solar resource assessment project to German firm", 26 December, available at: www.qatar-tribune.com/data/20111212/content.asp?section=nation1_3 (accessed 27 December 2011).

UAE Interact (2010), "RAK's solar islands could power emirate", available at: www.uaeinteract.com/docs/RAKâ€™s_solar_islands_could_power_emirate/42511.htm (accessed 26 November 2011).

Uckat (2011), "Market overview and update: renewable energy and energy efficiency in 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 (accessed 26 November 2011).

Utilities-Me (2010), "Oman considering solar-powered desalination plant", available at: www.utilities-me.com/article-470-oman-considering-solar-powered-desalination-plant/ (accessed 26 November 2011).

Whitmore, C. (2011), "Phoenix Solar chosen by Saudi Aramco to build 3.5 MW plant", *PV Tech*, available at: www.pv-tech.org/news/phoenix_solar_chosen_by_saudi_aramco_to_build_3.5mw_plant (accessed 20 December 2011).

(The) World Bank (2010), *Subsidies in the Energy Sector: An Overview*, The World Bank, Washington, DC.

World Resources Institute (2009), *Climate Analysis Indicators Tool*, World Resources Institute, Washington, DC.

Further reading

Doukas, H., Mannsbart, W., Patlitzianas, K.D., Psarras, J., Ragwitz, M. and Schlomanna, B. (2007), "A methodology for validating the renewable energy data in EU", *Renewable Energy*, Vol. 32 No. 12, pp. 1981-98.

About the authors

Dr Rabia Ferroukhi is currently Senior Policy Advisor at the International Renewable Energy Agency (IRENA) in Abu Dhabi, UAE. Prior to her work in carbon project development at MASDAR, Rabia has mainly focused on energy and development-related issues for over 15 years with different governments in the Middle East and North Africa, energy companies in the Mediterranean region, and international institutions. Rabia holds a Masters in Applied Economics and a PhD in Economics from the American University in Washington, DC.

Noor Ghazal-Aswad is an architectural engineer currently working as a consultant at the International Renewable Energy Agency in Abu Dhabi, United Arab Emirates. She has an MSc in Engineering Systems Management from Masdar Institute of Science and Technology (MI) and a BSc from the Architectural Engineering Department at the United Arab Emirates University. Her research interests lie in the area of sustainable development and renewable energy deployment policies and institutional frameworks.

Stella Androulaki is an Electrical and Computer Engineer (NTUA) and also holds a Computer Science degree (University of Crete) and a Master in Techno-Economic Systems (NTUA). Mrs Androulaki is currently a PhD candidate at the Decision Support Systems Laboratory (NTUA) and works on methods of multi-criteria analysis as well as optimization methods and decision support systems with applications in energy resources management and economics of energy. Through the projects in which she has been employed she has gained experience in investments evaluation, operations research and risk assessment in the sector of sustainable energy.

Diala Hawila is pursuing her Master's in Systems Engineering and Management at MI. Her thesis research is focused on measuring renewable energy readiness (RE-readiness) in developing countries and it was backed up by an internship at the International Renewable Energy Agency (IRENA). Prior to joining Masdar Institute, Diala worked as a Senior Consultant at PricewaterhouseCoopers (PwC).

Toufic Mezher is a Professor of Engineering Systems and Management at MI. Before Joining MIST, he was a Professor of Engineering Management at the American University in Beirut from 1992 to 2007. He earned a BSc in Civil Engineering from University of Florida, and a Master and ScD in Engineering Management from George Washington University in 1988 and 1992, respectively. His research interests include sustainable development, engineering management, renewable energy management and policy, building knowledge-based economies and innovation systems.