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A review of progress in renewable energy implementation in the Gulf Cooperation Council countries

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ABSTRACT

In an effort to diversify economies and reduce high oil dependency, the Gulf Cooperation Council (GCC) countries plan to increase the use of renewable energy sources to meet the challenges of a post-oil future. The Accession to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, which require a commitment to reduce greenhouse gas emissions, has started a process of environmental awakening in the GCC countries. This paper reviews the publications on renewable energy with reference to the GCC countries since 2005. The objective was to investigate the benefits of funding and investing in renewable energy projects in the GCC countries. The article shows that the GCC countries have begun to adopt a more pro-active approach toward renewable energy that will help progress the GCC countries towards sustainability. The reorientation of strategies and policies toward renewable energy is evolving in the GCC countries.

1. Introduction

Bahrain, Kuwait, Oman, Qatar, Kingdom of Saudi Arabia (KSA), and the United Arab Emirates (UAE) make up the Gulf Cooperation Council (GCC) and hold approximately 40% of the world's known oil reserves and 21.7% of the world's known gas reserves (OAPEC, 2012). KSA, UAE and Kuwait are within the top ten oil producers in the world, and key information concerning the GCC countries is summarized in Table 1. The large oil and natural gas resources and the greater competitiveness of conventional energy supply technologies based on oil and gas are their primary energy characteristics (Doukas et al., 2006).

A combination of brisk economic expansion and population growth is fueling a rapid increase in energy demand in the GCC countries. The low energy prices in the GCC countries provide a compelling reason for foreign companies to operate there. An increasing number of energy-intensive industries, such as the aluminum, petrochemical, and steel industries, are moving to these countries to take advantage of the inexpensive energy, minimum taxation and relatively inexpensive labor (Saif, 2009). However over-dependence of the labor market on inexpensive foreign labor negatively influences the productivity. The energy consumption in the GCC countries has grown by 74% in the period between 2000 and 2010 (Kinninmont, 2010) and is projected to increase by approximately 10–15% between 2010 and 2020. The rate of

Abbreviations: A/C, Alternating current; BIPV, Building-Integration Photovoltaic; BIWE, Building-Integration Wind Energy; CCPI, Climate Change Performance Index; CCS, Carbon capture and sequestration; DNI, Direct normal irradiance; DOE, US Department of Energy; ergo, Energy credit currency; ERI, Energy Research Institute; EU, European Union; FIT, Feed-In-Tariff; GDP, Gross domestic product; GCC, Gulf Cooperation Council; GHG, Greenhouse gas; GSM, Global System for Mobile; GSR, Global solar radiation; HOMER, Hybrid Optimization Model for Electric Renewables; HVDC, High voltage direct current; IRENA, International Renewable Energy Agency; IWPP, Independent Water and Power Producers; KACST, King Abdulaziz City for Science and Technology; KAUST, King Abdullah University of Science and Technology; NREL, US National Renewable Energy Laboratory; PEM, Polymer Electrolyte Membrane; PV, Photovoltaic; PPP, Purchasing power parity (PPP); OECD, Organization for Economic Cooperation and Development countries; STC, Standard test conditions; SPP, Solar power plants; SWH, Solar water heating; TFE, Total ecological footprint; UNFCCC, United Nation's Framework Convention on Climate Change; WECS, Wind energy conversion systems; WSC, Wind shear coefficients.

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increase in electric energy consumption in the GCC countries in the period between 2005 and 2009 was 8.87%. The per capita electric energy consumption in 2009 was 11,362 kWh, which is 3.9 times the world per capita, 0.8 times the per capita in the USA, 4.2 times the per capita in China and 1.7 times the per capita in the EU (Alnaser and Alnaser, 2011). The per capita electric energy consumption of the GCC countries for 2013 is given in Table 1. The per capita electric energy consumption during the period 2007–2035 in the GCC countries is projected to increase at an annual rate of 2.5%. Considering the projected rise in electric energy demand, up to 100 GW of additional generation capacity is required over the next ten years in the GCC countries. Table 1 also shows the peak demand and the current electric power-generating capacity in GCC Countries.

Over the next twenty years, the GCC countries are likely to experience one of the most rapid growth rates in economic and energy consumption in the world (Ebinger et al., 2011). To guard against rising energy requirements, the energy industry in the Middle East will require investments of approximately 10^6 MUSD over the next 20 y.

Ferguson et al. (2000) found a strong correlation between a country's electricity usage and the level of economic development and growth. Any large-scale switch away from energy-intensive economic activity is likely to act, at least in the short-term, to the detriment of the competitiveness of the GCC countries in terms of trade. However, (Payne, 2010) suggested that empirical results have yielded mixed results in terms of the four hypotheses (growth, conservation, neutrality, and feedback) related to the causal relationship between electricity consumption and economic growth. Nevertheless, there are opportunities for the countries of the GCC to achieve the parallel objectives of reduced carbon emissions and domestic consumption of valuable oil and gas resources and increased economic diversity that does not require a major structural change to their economy but still provides significant potential net benefits, both in terms of carbon-reduction and economic performance. These opportunities lie in the development and adoption of technologies and improved management systems in the areas of alternative energy, energy efficiency and carbon capture and sequestration (CCS) (Ebinger et al., 2011).

On a purely economic basis, the GCC's investment in the development of renewable energy offers a number of key benefits. First, facilitating the diversification of the energy supply mix away from a reliance on finite fossil fuels will increase long-term energy security by exploiting renewable energy resources. Second, reducing the domestic consumption of fossil fuels will increase oil and gas export revenue potential. Third, support for this sector will create opportunities for capital investment. Finally, the resulting economic development can potentially create high-value jobs within the region that can contribute to the full renewable-energy value chain, including R&D, manufacturing, and local and international deployment (Mondal and Khalil, 2012). The special report on renewable energy sources and climate change mitigation provides a comprehensive review concerning these sources and technologies, the relevant costs and benefits, and their potential role in a portfolio of mitigation options (IPCC, 2012). The trade-off between economic cost and environmental benefits justifies the support for the promotion of renewable energy because the adoption of such technology will have social benefits beyond the cost considerations (Radhi, 2012).

A study (Al-Mulali and Foon Tang, 2013) suggested that in the GCC countries, the per capita CO_2 emission, per capita real foreign direct investment, per capita energy consumption, and per capita

Table 1
Key information of GCC.

Country/Key information	KSA	Kuwait	Bahrain	Oman	Qatar	UAE
Economic information (UNDP, 2013)						
GDP (2005 PPP, 10^9 $) 2011	601.8	135.1	26.9	72.1	145.8	333.7
GDP per capita (PPP[a]) (2005 PPP $) 2011	21430	47935	21345	25330	77987	42293
Oil & gas information (OAPEC, 2013)						
Proved oil reserves (10^9 m^3) at end of 2011	42.195	16.137	0.015899	0.875	4.023	15.55
Proved natural gas reserves (10^9 m^3) at end of 2011	8150	1784	92	950	25030	6091
Total primary energy production (GWh) (2010)	7251817	1648134	160954	831287	192292	2239350
Electric energy (generation/consumption) (IEA, 2012; OAPEC, 2013)						
Electric energy consumption (GW h)	256331	54932	14300	13268	27724	81335
Peak electric load (MW) (2012)	51965	11904	2967	4189	5576	18247
Installed electric generation capacity (MW) (2012)	62132	14703	3227	4650	8761	26142
Per capita electric consumption (kWh/y) (2010)	7967	18318	9813	5934	14995	5741
Environment related information						
Per capita CO_2 emissions (10^3 kg) (2008) (UNDP, 2013)	16.6	30.1	19.3	17.3	49.1	25.0
Commitment to international community (UN, 2011)	Accession to UNFCCC and the Kyoto Protocol: 31 Jan 2005	Accession to UNFCCC 11 Mar 2005	Accession to UNFCCC and the Kyoto Protocol: 31 Jan 2006	Accession UNFCCC and the Kyoto Protocol: 19 Jan 2005	Accession to UNFCCC and the Kyoto Protocol: 11 Jan 2005	Accession to UNFCCC and the Kyoto Protocol: 26 Jan 2005
Renewable energy potential						
Solar power	✓	✓	✓	✓	✓	✓
Wind power	✓	✓	✓	✓	✓	✓

[a] Purchasing power parity (PPP).