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Shifting to Renewable Energy to Mitigate Carbon Emissions: Initiatives by the States of Gulf Cooperation Council

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Abstract

The Gulf Cooperation Council (GCC) countries approximately have 40% of world's proven oil reserves and 21.7% of world's known gas reserves. Low energy costs compiled with low taxation make it lucrative to foreign energy-intensive companies to operate in the region. Energy consumption in GCC has increased by 74% in the period between 2000 and 2010 and it is projected to increase by approximately 10% to 15% between 2010 and 2020. Embracing the general commitment by GCC states to reduce greenhouse gas emission (GHG) of United Nation Framework Convention on Climate Change (UNFCCC) has started the process of environmental awakening in the GCC countries due to its high vulnerability to the effects of climate change. This paper reviews the trends in shift to renewable energy with reference to GCC and also the co-benefits of investing in renewable energy. Solar plant and Building-Integrated Photo-Voltaic (BIPV) systems are the most invested projects. However in the long run, policies and strategies are needed to ensure the successful and larger implementation of mitigation objectives.

Keywords

Renewable Energy, Climate Change, GCC States

1. Introduction

With regards to the climate change policy of the Gulf Cooperation Council (GCC), a trade bloc consisting of six Arab States of the Arabian Gulf (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) was created in 1981. The GCC member states are the major oil and natural gas producing countries [1]. GCC states have approximately 40% of world's known oil reserves and 21.7% of world's known gas

reserves [2].

Their economies are heavily depended on the crude oil and natural gas. Exploitation, extraction, processing, transportation and use of theses fossil fuels are associated with several environmental issues including climate change. Carbon dioxide (CO_2) is the most abundant anthropogenic greenhouse gas responsible for global warming, released in enormous quantity at different stages of crude oil production. **Figure 1** and **Figure 2** show natural gas and oil consumption levels of the GCC countries in 2013 based on International Energy Agency (IEA) report, among which Saudi Arabia and United Arab Emirates are the leading consumers [3]. Indeed, these member states are still leading the international ranking of climate-polluters. According to 2009 global ranking of CO_2 emissions (metric tons per capita), Qatar ranked first, Kuwait third, the United Arab Emirates fifth, Bahrain seventh, Saudi Arabia eleventh, and Oman thirteenth, among a total of 214 countries [4]. Power plants are the major source of CO_2 emissions.

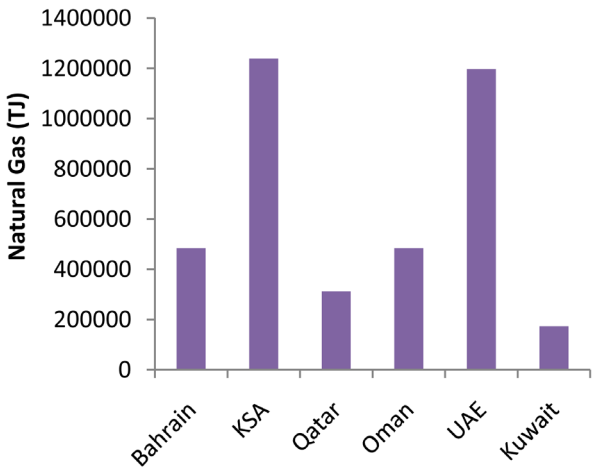

Figure 1. Natural consumption (TJ), 2013 [3].

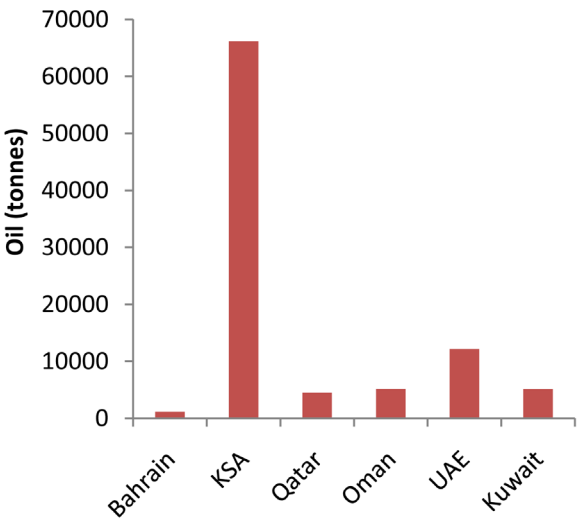

Figure 2. Oil consumption (10^3 tonnes), 2013 [3].

This is attributed to three main factors; first of all, the phenomenon of growth of urban population and increase in their purchasing power due to influx of migrant workers to GCC countries has led to reinforcement of national population growth. Second, the process of economic diversification and industrialization and thirdly, the relatively low price of energy to industry [5].

Electricity consumption is increasing at faster rate in GCC countries: 12.4% from 2005 to 2009 (3.15% per year). This rate is much higher than the world average of 2.2% for the same period. Average per capita electricity consumption in GCC region was 10,976 kilowatt-hour (kWh) in 2009, which was 3.9 times more than the world average of 2806 kWh [6]. Kyoto protocol has ignited political and public concern regarding the impact of energy utilization on climate and environmental degradation resulting in a move at global level towards a low-energy consumption culture [7]. The United Nations report on global warming "*Climate Change* 2014: *Impacts, Adaptation and vulnerability*" calls for a major shift from the usage of fossil fuel to renewable resources [8]. Development of renewable energy technologies is now globally accepted as a crucial component of providing an integrated solution to reduce greenhouse gas emissions, fostering innovation and providing access to secure, clean and affordable energy [9].

Though, all GCC countries have ratified the International Renewable Energy Statute of increasing the share of renewables in their energy grids and yet, there is considerable variation in the adoption of renewable energy technologies; while others are actively engaged in the development of renewable energy, other countries appear to be lagging behind [4].

In order to contribute to domestic energy security as well as long-term economic and environmental sustainability, the GCC countries must act decisively to take the merits from many benefits of investing in renewable energy projects for the local market; the greater usage of renewable energy will lead to lesser oil and gas consumption which can remain for export, increasing revenue for the GCC countries [9]. This paper reviews the trends in shift to renewable energy with reference to GCC countries with co-benefits of investing in renewable energy but also suggests policies and strategies needed to ensure the successful and broader implementation of mitigation objectives.

2. Drivers of Electricity Consumption

A study postulate [10] that there is a positive linkage between trade, income and energy consumption in the Middle East, so any intervention in energy conservation is likely to have profound impact on economic growth. Internal migration has led to increasing population density in urban areas and this has resulted in high proportion of the population enjoying the significant improved living standards resulting in an increased size of average dwelling, universal reliance on air conditioning and high usage of household appliance [2]. Another determinant of energy consumption in GCC countries is price, the cost of energy to consumers and industries are low [11]. It is reported that high energy consumption in GCC states is due to growth of development and infrastructure and investment in energy [12]. **Table 1** shows that electricity consumption in GCC has

Table 1. Electricity consumption in GCC countries for 2011 and 2013 compared with USA, EU, Africa, China and World [3].

Country/Region	Consumption TWh (2011)	Consumption TWh (2013)	Population (10^6) (2011)	(MWh/capita), 2011
Bahrain	22.9	24.58	1.29	17.71
KSA	226.57	264.0	27.76	8.16
Qatar	28.82	32.51	1.91	15.08
Oman	19.03	23.37	3.03	6.29
UAE	92.04	98.58	8.93	10.31
Kuwait	50.38	53.58	3.13	16.12
GCC Total	**439.74**	**496.62**	**46.05**	**73.67**
USA	4127.31	4109.84	312.03	13.23
EU	3099.55	3066.53	506.30	6.12
Africa	622.00	649.15	1056.10	0.59
China	4432	5121.93	1340.00	3.31
World	20,444.69	21,537.90	6950.94	2.94

increased at a faster rate. USA and EU has been able to decease their total consumption from 2011 to 2013, this is different in GCC where consumption has rather increased from 2011 to 2013. This attests to the fact that USA and EU are adopting renewable energy policies in reducing electricity consumption and overall GHG emission reductions.

3. CO_2 Emissions in GCC

GCC countries are ranked as one of the top per capita contributors to global pollution. Only 0.6% of the world's populations resides in the GCC countries, yet the region contributes 2.4% of greenhouse gas (GHG) emissions [13] as shown in **Table 2**. Energy intensities, CO_2 per GDP and CO_2 emissions per capita in GCC countries are higher than European Union and Organization for Economic Cooperation and Development (OECD) [14]. According to International Energy Agency [15] all GCC countries fall in the top 25 countries responsible for the highest per capita CO_2 emissions.

According to a report [16] on total CO_2 emissions in kilo tons (kt) in 2009, GCC accounted for 2% compared to 9% of European Union and 13% of United States as shown in **Figure 3**.

4. Climate Change Vulnerability of GCC

GCC countries are ranked as high category for vulnerability to the effects of climate change. The social, economic and ecological impact of change in climate is expected to

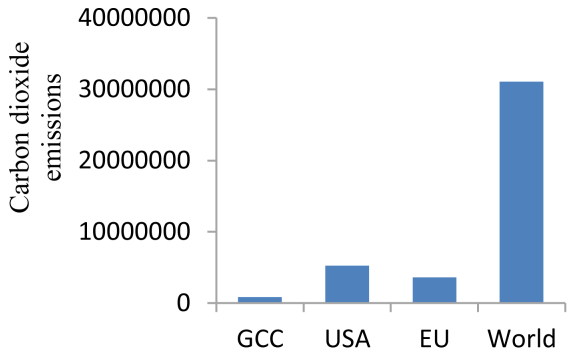

Figure 3. CO_2 emissions (kt) in 2009 [16].

Table 2. Per capita and total CO_2 of GCC in 2009 [17].

Country	Per capita CO_2 emissions, 2009 (10^3 kg/person)	Total CO_2 emissions, 2009 (10^3 kg)
KSA	78	438
Kuwait	31	84
Bahrain	43	31
Oman	17	49
Qatar	78	64
UAE	41	194

be higher in GCC countries than the rest of the world [2]. It is reported that in addition to environmental stress which is already increased by economic development, the current GCC countries development policies are detrimental to economic sustainability and should be revised or well-adjusted with novel policies to counter unplanned environmental harms of development [18].

GCC countries are confronted to multi-climate change challenges such as desertification, loss of biodiversity, water scarcity, and sea level rise. The region is also faced with high humidity, high temperature and salt water intrusion into aquifers [19]. Urban planning and clean energy consumption can avoid emission of pollutants while ensuring sustainable development in GCC countries [20].

5. Renewable Energy in GCC

Increased energy consumption in the GCC region is, to a certain extent, an inevitable outcome of socio-economic development. However, in the prevailing situation of fluctuation in oil price, rapid population growth and increasing demand of electricity consumption, GCC governments are fully aware that they cannot depend on oil for their revenue forever. As a result, the usage and development of renewable energy resources could make a significant contribution towards improving environmental protection as well as ensuring continuity of oil supplies in secure and stable conditions within the regions [21]. Among the renewable energies, solar and wind are the fastest growing sec-

tors, primarily due to indigenous abundance and relatively advanced technological development [22]. Solar energy is the most promising source of energy since conditions for solar energy potential for GCC are the most favorable in the world: GCC countries are in a rainless region in the world with 80% clear skies throughout the years extending from North Africa to Southern Asia [13]. GCC has a substantial solar radiation with Kingdom of Saudi Arabia (KSA) having the highest resource potential.

To deploy renewable energy technology in a country, it is imperative to evaluate the renewable energy resource potential of that country, these includes solar radiation, wind speed and availability of lands for solar PV, Concentrated Solar Power (CSP) and wind farms for electric power generation. The higher the resource value score, the higher the renewable energy readiness score.

Table 3 shows global average solar radiation for PV is 2083 kWh/m^2/year and that of direct solar radiation for CSP is about 2208 kWh/m^2/year but wind energy potential is moderate with an average speed of 6 m/s which varies substantially among the countries [6].

The substantial solar and wind with Qatar, Kuwait, Bahrain and Oman receiving renewable energy readiness score of 5.6, 5.5, 5.3 and 5.2, respectively due to their substantial solar and wind resources. UAE and KSA had a lower score of 4.7 and 4.55 respectively due to their inadequate wind resources.

6. Some Current Renewable Energy Projects in GCC

Two most viable renewable energy resources projects common to all GCC countries are solar and wind.

6.1. Bahrain

Bahrain pays special attention in the issue of renewable energy and cleaner energy. The authorities in the Kingdom are consistently searching for novel and alternative energy source which is suitable for the local environment. In February 2010, Bapco (Bahrain

Table 3. Solar and wind potential in GCC.

Country	PV Global Solar Radiation (kWh/m^2/year)	CSP Global Solar Radiation (kWh/m^2/year)	Solar Radiation (kWh/m^2/year) Score	Wind Speed (m/s)	Hours of Full Load/Year	Score
Bahrain	2160	2050	5.1	5.0 - 6.0	1360	5.5
KSA	2130	2500	5.6	2.5 - 4.5	1789	3.5
Kuwait	1900	2100	5.9	5.0 - 5.5	1605	5.2
Oman	2050	2200	5.4	4.0 - 6.0	1463	5.0
Qatar	2140	2200	5.2	5.0 - 7.0	1421	6.0
UAE	2120	2200	5.4	3.5 - 4.5	1176	4.0

Source: [6].

Petroleum Company) installed First Zero Emission House project of 7 kW solar, wind and fuel cell. The house is made up of 4 kW photovoltaic, 1.5 kW wind turbine and 1.2 kW fuel cell. Bapco has also formed a team consisting of University of Bahrain, Electricity and Water Consumption Authority, Ministry of Housing, Ministry of Work, Ministry of Municipality and Agriculture and National Oil and Gas Authority (NOGA) in ensuring follow up and promotion of renewable energy projects in the Kingdom and the world at large [12].

In 2007, two 225 kW wind turbines were installed at Bahrain World Trading Centre generating approximately 11% - 15% of building's electricity requirements. A 5 MW solar PV was launched in 2012, a joint project between Bapco, National Oil and Gas Authority (NOGA) and two other United States based firms; Caspian Energy Holdings and Petra Solar. University of Bahrain Engineering Faculty has produced two mobile solar plant, one for water desalination and a 1.4 kW/100W hybrid wind/solar power generation system [9]. There is solar panel factory in Bahrain in collaboration with a Dutch company at a cost of US$ 200 million [12].

6.2. Saudi Arabia

In 2010, King Abdullah's realization of 10 MW initiatives for desalination plant using solar generated energy led to two solar plants in both Al-Khafji and Al-Oyainah. In 2011, Saudi Electricity Company as part of pilot project, commissioned 500 kW solar plants in Farasan Islands and these plant is capable of being expanded to 6 - 8 MW.

A solar thermal plant with an area of 36,300 m^2 was commissioned in 2012, including an addition of Aramco King Abdullah Petroleum Studies and Research Centre solar park in Riyadh which was expanded from 3.5 MW to 5.3 MW [9]. A Vision Electro Mechanical Co, a subsidiary of Construction Products Holding Company has established a company with an amount of $150 million for the development, manufacturing and operation of solar power plants to generate electricity in the region [12].

A solar village project of an area of approximately 67,180 m^2 utilizes a computerized 350 concentrator solar PV electricity-generating power station that includes 160 PV arrays covering an area of 4000 m^2. The project produces an output of 350 kW direct current (DC). The station distributes 1 to 1.5 MWh/d of electric energy to three rural villages namely: Al-Jubailah., Al-Uyaynah and Al-Higera [2].

6.3. Kuwait

A total of 280 MW solar power plants amounting to US$ 720 million were installed in Al-Abdaliya and Al-Jahraa**.** The project was sponsored by partnerships of Technical Bureau through Government of Kuwait and Toyota Tsusho Corporation, Japan [22].

There are number of Research and Development (R&D) renewable energy projects including two projects on solar cooling, PV systems in street lightning and traffic sign and 151 kW installed solar power capacity [9]. There is solar thermal application projects such as Sager Al-Rashood Kindergarten with an area of 300 m^2 90 solar collector. Thermal electricity project was carried out in places such as Salwa (Kuwait English

School) with daily electricity load of 630 PV modules and 110 batteries with total electricity production of 24.2 kW [12].

6.4. Oman

Petroleum Development Oman (PDO) launched 7 MW solar thermal plant project to be constructed by Glass Point Company with the aim of producing 11tons/h of high pressure steam used to extract 33 thousand barrels of oil as well as provision of 24hour heating [9]. Ministry of Regional Municipalities and Water Resources installed wind powered electric water-pumping system in remote part of Oman [21]. There is 200 MW concentrated solar power (CSP) project located in Al-Dakhiliya which cost US$ 600 million [22].

A 25 MW wind energy project is located in Marmul in the southern part of Oman [23]. SQU Ecohouse—project funded by the The Research Council (TRC), the roof top of the building was installed with 156 m^2 of 20 kW peak PV panels [7]. In Sohar, the roof top of Majan Electricity Company (MJEC) was installed with 50 kW solar PV system covering an area of 325 m^2 [24].

6.5. Qatar

Inauguration of Qatar Solar Energy (QSE) in 2014 was one of the vertically integrated PV module production facilities in the Middle East and North Africa (MENA). The 300 MW facility is located in Doha [9]. In 2008, Qatar together with United Kingdom established a joint clean energy investment fund of US$ 400 million to attract foreign investment projects relation to clean energy technology development [4]. Energy efficient house was constructed in Baytna villa, a project which was undertaken by Qatar Green Energy Council was constructed with PV array with a peak power of 34 kW [7]. Also, under the auspices of Qatar Foundation, Qatar Environment and Energy Research Institute was inaugurated in 2011 to carryout research in the area of solar photovoltaics, energy storage technologies and grid integration in collaboration with Qatar Solar Technologies, Pacific Northwest National Laboratory, Oak Ridge National Laboratory and University of California, Los Angeles [4]. Solar Test Facility at Qatar Science and Technology Park is 35,200 m^2 open field, grid-connected test site located at Education City, 10 km from Doha, the aim of this facility is to contribute in achieving Qatar's sustainable energy targets [25].

6.6. UAE

Solar PV is growing at a faster rate and the United Arab Emirates leads the Gulf Region in PV electricity generation. UAE launched a 100 MW concentrated solar power (CSP) Sham-1 at Madinat Zayed at Abu Dhabi in March 2013 extending over an area of 2.5 km^2 and its considered as world largest CSP [26]. This will be followed by two other projects Sham-2 and Sham-3 with extra capacity of 150 MW. Masdar city in UAE is equipped with solar PV facility [20].

There are also small scaled solar PV projects including: 1 MW rooftop installation at

Masdar Institute; Yas Marina circuit is equipped with 291 kW PV array, Masdar city parking shade has been installed with 204 kW PV; and 200 kW mounted an Presidential Sea Palace. Al Qarneed Island and Marawah Island have solar PV of 0.75 MW and 0.49 MW respectively [9]. Waste-energy project in Sharjah which is completing tendering will produce 53 MW of power [27]. A large 850 kW wind turbin has been constructed at Sir Bani Yas Island located at 250 km southwest Abu Dhabi [26]. International research collaboration was signed between Masdar Institute and Massachusettes Institute of Technology (MIT) for the development of renewable energy technologies. Among some of the research foci includes: *transformations* such as advanced solar energy technologies, offshore and onshore wind energy, biofuels, geothermal, wave and tidal energy; *global systems* including science and policy of global change, building and urban systems and vehicles and transportation system and *innovations* which comprises carbon capture and sequestration, power electronics, heat management [4]. The iconic tower—Burj Khalifa was installed in April 2010 with 378 solar collector panels of 2.7 m^2 area each to heat about 140,000 L of water per day for in-house consumption with energy savings equivalent to 3200 kW per day. Turbine being the third largest in solar desalination after US and Saudi Arabia is taking initiatives to use solar energy for such purpose. The Environment Agency-Abu Dhabi (EAD) constructed 22 small scale solar desalination plants which are capable of producing 11,000 cubic meters of water a year [22].

7. Future Renewable Energy Projects in the GCC

The main investors of renewable energy in Middle East are GCC countries, it is expected that by the year 2020, the new solar and wind energy would have reached 10 GW. World Energy Council (WEC) estimated that the total current CO_2 emission to the planet caused by the GCC countries are not more than 2.25% (0.1% for Bahrain, 0.4% for UAE, 0.1% for Oman, 0.2% Qatar, 1.2% Saudi Arabia and 0.2% for Kuwait). GCC countries will require extra 100 GW of power for the next ten years to meet its growing energy demand [12].

However, planning energy processes requires critical study of demand and supply, prediction of trends of input-output items based on economic, technological models and strategies to diversify the sources of energy [9]. International Renewable Energy Agency (IRENA) based in Abu Dhabi estimates that the six GCC countries returns through renewable energy integration could reach US$ 200 billion [22]. This review tried to summarize in **Table 4**, the GCC state's national future projections on renewable energy projects in the coming years.

8. Co-Benefits of RE to GCC Countries

Apart from reducing the future impact of climate change by GCC countries through investment in renewable energy technologies and projects, GCC states will also benefits from reduction in highly subsidized domestic fuel consumption and exportation abilities. They will be well prepared during post-oil age, thus their energy infrastructure

Table 4. Future renewable energy for GCC countries.

Countries:	Bahrain	Kuwait	Oman	Qatar	Saudi Arabia	UAE
Future Renewable Energy (RE) projects and targets	Renewable energy is planned to reach 5% - 7% of Power generation capacity (PGC) Collaboration between industry (National Oil and Gas Authority, Bahrain Petroleum Company) and academic institutions (University of Bahrain) for 3 MW solar and 2 MW projects to be implemented in next five years [8] US$211 million Green City Project using Building Integrated Photovoltaic (BIPV) [22]	RE is planned to cover 1% and 15% for 2020, 2030 respectively -first phase of 70 MW by 2016 in Shagaya -second phase of 100 MW will be operational by 2020 -third phase with 2000 MW capacity will be operational in 2030 [28]	Ten percent of electricity will be covered by RE by 2020 [29] There will be power generation and desalination water supply from 2012-2018 [29] Six RE pilot projects includes: -292 kW PV solar project in Al Mazyonah -1500 kW project location to be confirmed -200 MW solar plant is expected to be constructed -100 kW PV project in Hiji -4200 kW wind project in Siah Al Khairat [24] Reduction of transmission and distribution power loss for 14% in 2010 and 10% in 2014 [29] A $ 2 billion project of generating about 400 MW solar power was announced by Tera Nex Financial Engineering AG Switzerland and Middle East Best Group of Funds [3]	RE will cover 2% by 2020 (of about 1.8 GW which includes 200 MW solar technology mix of 10 MW phase 1 pilot plants and phase 2 involving private sector of about (150 - 200 MW), RE will reach 20% by 2030 [29] Twenty percent decrease in per capita electricity consumption by 2017 [29] Polysilicon PV system in Ras Laffan City with 8000 metric tons per year for 6.5 GW when in full capacity [29] Development of biofuels in partnership with Qatar Airways, Qatar Science and Technology Park and Qatar Petroleum [30] Construction of 5 stadia with solar technology cooling for Qatar World Cup 2022 [8]	There will be 5 GW of solar by 2020 and RE expected to reach 54.1 GW by 2032 (23% - 30% of power generation capacity [29] Fourteen percent electricity peak reduction demand by the Electricity Co-Generation Regulatory Authority and Saudi Energy Efficiency [29] Proposed Competitive Procurement Process (CPP) Saudi Arabia's King Abdullah City for Atomic and Renewable Energy Program will consist of: -41 GW solar power (25 GW CSP/16 GW PV) -9 GW from wind -4 GW from thermal and waste energy -17 GW from nuclear energy (which will constitute 18% - 20% of power generation capacity [8]	By 2020, there will be 800 MW solar power with 7% load to Abu Dhabi and 1% to Dubai The share for RE will be increased by 5% and Nuclear Power Plant share in Abu Dhabi has been planned to increase by 12% by 2030 with four nuclear plants planned by the year 2020 [28] Fifteen percent electricity demand was planned starting from 2010 By 2030, there will be 1 GW PV and CSP Mohammed bin Rashid Al Maktoum Solar Park in Dubai which will cover 48 km^2 area (1st Phase will be 13 MW capacity PV) [31] Masdar Institute is considering in building a wind turbine farm capable of producing 30 GW at Sir Bani Yas Island, this turbine will be the largest onshore wind turbine farm in Middle East [26]

would be ready for a period where domestic oil and natural gas get limited. Also more sustainable policies in renewable energy will give GCC countries a better reputation in international policy arena [1]. The use of solar energy will especially leads to the following benefits: reclamation of land; reduction on emphasis on national power grid network; ameliorate water quality problems across the countries since there will be reduction in groundwater pollution from oil extraction and also accelerated electrification projects in rural remote areas [28].

Some of the manifold benefits that GCC countries can derive from developing re-

newable energy projects are:

- Diversifying the economy to lessen the burden on aging power infrastructure.
- Provision of parallel energy support network to population boom and rapid urbanization.
- Promote capacity development for a knowledge-based economy.
- Better management of the demand-supply gap by compensating for indigenous shortage of oil or gas or both [22].

9. Policy Approaches and Strategies

GCC member states has established administrative capacities tackling climate change issues: the Ministry of Environment and Climate Affairs in Oman, the Public Commission for the Protection of Marine Resources, Environment and Wildlife in Bahrain, the Environment and Public Authority in Kuwait, the Supreme Council for the Environment and Natural Reserves in Qatar, the Presidency of Meteorology and Environment in Saudi Arabia, and the Federal Environment Agency as well as the Ministry of Environment and Water Resources in United Arab Emirates [13]. These institutions, however, often have some limited capacities and minimal influence when it comes to domestic policy processes. No GCC country has a consistent policy framework regarding renewable energies and energy efficiency but there are remarkable ongoing projects in the GCC countries which are also known to the global community. As shown in **Table 4**, GCC states also have national future projections on renewable energy projects in coming years.

Developing a self-sustainable domestic market for renewable energies needs concerted efforts which aid in further development, application, and diffusion of those resources [29]. Focusing on policy formulations framework that encourage transition to renewable energy development pathway, the development and changes in policies as well setting up institutions may help in surmounting the current structural weakness which will spur a wide spectrum in renewable energy source deployment [30]. Power Purchasing Agreements (PPA) whereby partnership between Governments and developers on renewable energy is fruitful and provides equal opportunities to renewable energy source power to compete with the heavily subsidized conventional energy sources [29]. Adoption of renewable energy technologies from the pioneering countries can be infused through policy transfer [4]. Policy transfer can be seen as a set of "processes where a nation learn from or imitates policies implemented elsewhere through bilateral communication and direct interaction or exchange of experiences" [31]. This allows policy makers to search for alternative policy solutions that are successful in other countries. Hence, policy transfer concept can be used as a channel through which renewable energy policy and technological knowledge can be disseminated.

10. Conclusion

Renewable energy investments are increasingly growing in the GCC, primarily due to

the awakening in the region to stem the faster depletion of finite oil and gas reserves. This move in fact creates a platform to prepare themselves towards their commitment to UNFCCC in greenhouse gas reduction towards sustainable development. While some countries such as UAE and Saudi Arabia are leading the renewable energy projects, other members can leapfrog by employing policy transfer mechanisms, inter-regional collaboration and business partnerships. However many critics say, it will be a challenge to implement these renewable energy projects and technologies without clear cut policies and regulatory framework. Hence, GCC has to use stable and sustainable policies towards renewable energy deployment goals. These sustainable policies in renewable energy will also give them a better image in arena of international environmental and climate change policy. Research and development is important in realizing these goals since it creates knowledge-based economy and invests in human capital stock for the future generation. In addition the co-benefits of investing in renewable energy will immensely benefit the economy in the long-term future. Though any amount of efforts will take its own time, without a doubt the slow transition from being a hydrocarbon economy to low carbon economy is necessary and bound to happen at one point of time at least in the far future.

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