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# Challenges Facing Grid Integration of Renewable Energy in the GCC Region

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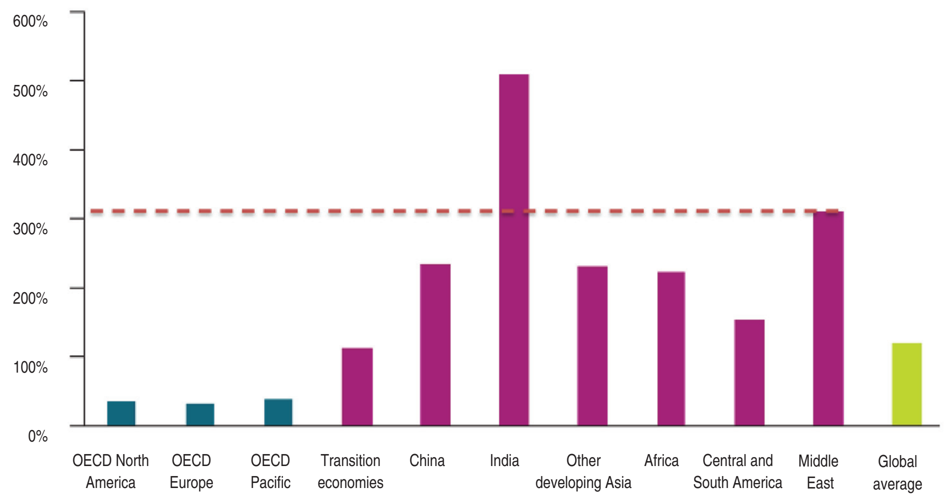
Established in Abu Dhabi on May 25, 1981, the Gulf Cooperation Council (GCC) comprises the following six Arabian Gulf states: United Arab Emirates, Bahrain, Saudi Arabia, Oman, Qatar and Kuwait (see Fig. 1). The GCC region covers a global area of 2,500,000 km.2 The GCC population reached an estimated 46.8 million in 2011, up sharply from 33.2 million in 2004, and is forecast to rise to 49.8 million in 2013. The GCC countries' global GDP reached $1.4 trillion in 2011,which is an increase of 29 percent over the previous year.

**Fig. 1: Map of the GCC region**

The GCC is likely to have a larger current account surplus than either Japan or Germany in 2012-13 as high oil prices boost exports. The actual spending of the GCC countries is projected to be higher, and this means more projects will be carried out in the region.

Over the past decades, the GCC countries have relied on oil as the main source of income and the entire economy revolved around it. However, along with economic development, growing industrial development has led to higher energy demand for local needs. Fig. 2 shows the world electricity consumption growth from 2007 to 2050. Notice that the Middle East region is expected to reach 300 percent growth in 2050. GCC energy consumption has grown 74 percent since 2000 and is projected to nearly double its current levels by 2020.

**Fig. 2: World electricity consumption growth, 2007-50**




Source: IEA, 2010.

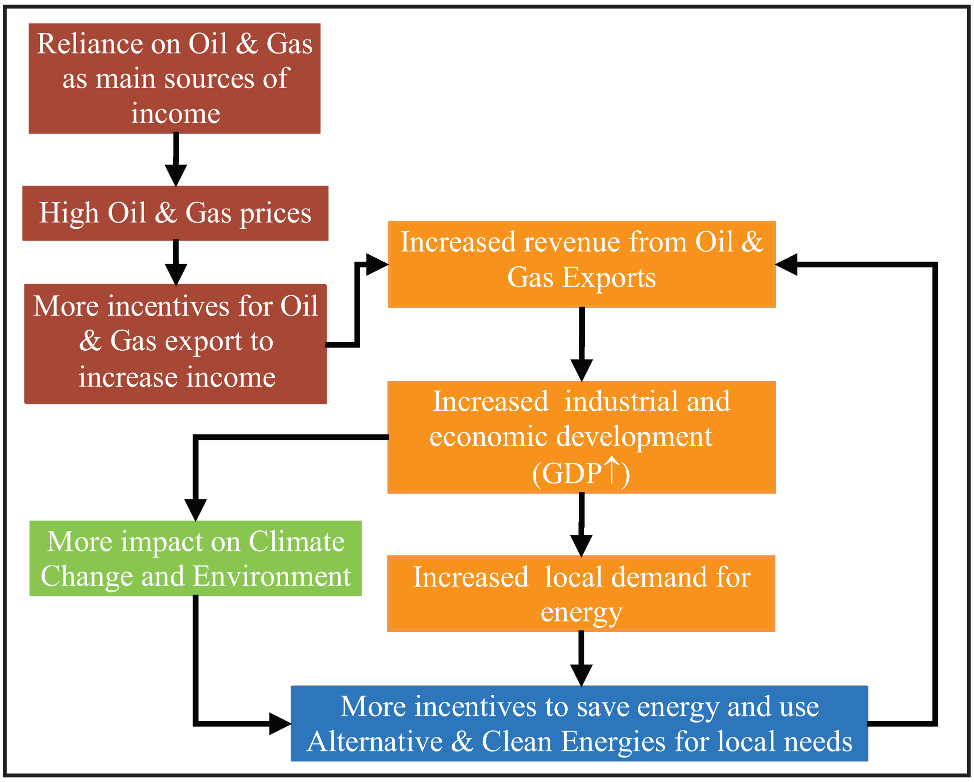
The recent growth in GCC energy demand – and electricity demand, in particular – comes at a time of rising global concern over carbon emissions and climate change. According to the World Economic Forum, the GCC nations are among those that will be most adversely affected by climate change, with:

- Increased pressure on scarce water resources and arable land
- Rising air pollution, and
- Increased likelihood of flooding in coastal areas

It is obvious that there is an urgent and strong need for adopting renewable energy in the GCC region to satisfy the huge electricity demand and, at the same time, reduce GHG emissions. Besides, the greater the use of renewable energy the lesser the local consumption of oil and gas, which can then be sold further increasing the revenue of the GCC countries. This would also facilitate the progressive modernization of the energy infrastructure, increasing its efficiency, which in turn would contribute to building a viable future for the coming generations.

Fig. 3 summarizes the reasons for the drive toward the application of renewable energy in the GCC region.

**Fig. 3: Justification for moving toward the use of alternative energy in the GCC region**



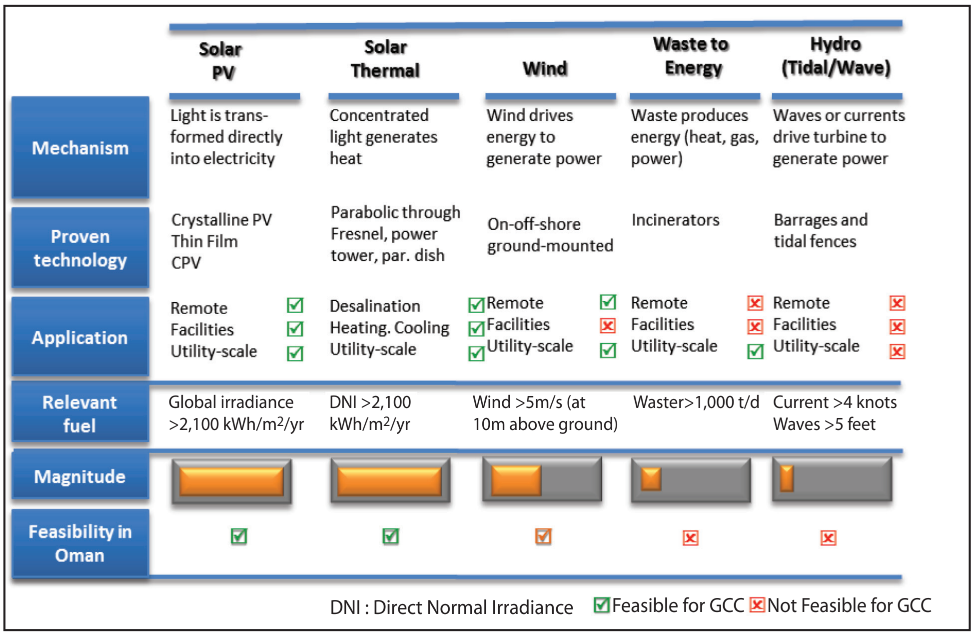

This paper presents the challenges of the application and integration of renewable energy in the grid for the GCC region. Section 1 presents the renewable energy potential in the GCC region. Section 2 discusses the suitable technologies for the region. Section 3 investigates the different barriers and challenges facing the application and grid integration of renewables. Section 4 gives some recommendations for helping the integration of renewables into the GCC grid. Finally, the concluding section sums up the paper.

## 1. Renewable Energy Potential in the GCC Region

Despite their heavy reliance on hydrocarbon fuels, the GCC countries have access to one of the world's most abundant solar resources. All six nations of the GCC have either embarked upon or are committed to investments in solar projects, with projects split between solar photovoltaic and solar thermal applications. The region also has sizable wind resources, although these vary widely across the GCC countries, and wind installations are at a less developed stage than their solar counterparts. Fig. 4 presents a feasibility comparison between the main renewable energy resources.

Notice that solar and wind energies are the most promising renewable energy resources for the GCC region. Notice also that solar energy has much more potential for application. Therefore, this paper will focus mainly on solar energy technologies.

**Fig. 4: Feasibility comparison of different renewable energies in the GCC**




## 2. Suitable Technologies for the GCC

### *Efficiency Reduction vs. Cell Temperature*

It is known that the performance efficiency of a solar cell is affected by its operating temperature. Table 1 shows an example of the sensitivity of different solar cells to temperature variations.

**Table 1: Effect of temperature on solar cells efficiency**

| | Efficiency Test Conditions at 25º [%] | Temperature Coefficient [%/ºC] |
|---|---|---|
| c-Si | 16 | -0.45 |
| a-Si | 9 | -0.30 |
| CdTe | 11 | -0.50 |
| CIG S | 12 | -0.55 |
| CPV System | 28 | -0.15 |

This is considered an important issue for the GCC region because of its hot climate. In fact, solar cells operating in the GCC region will not perform the same way as their counterparts operating in Europe.

### *Water Requirements*

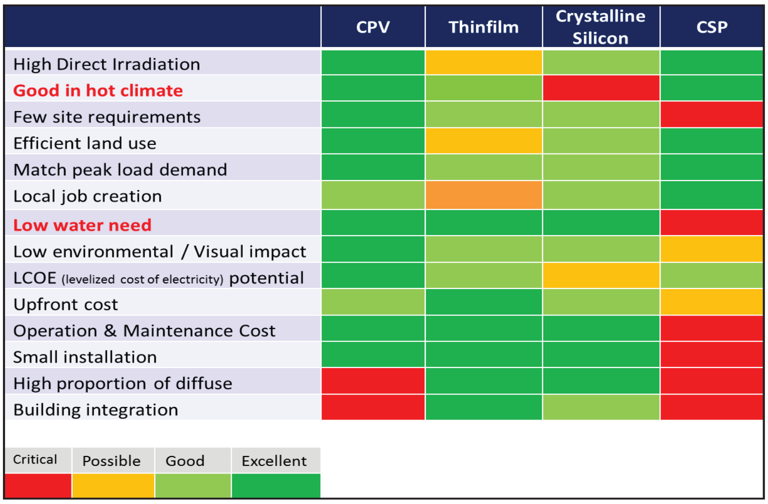
According to a US Department of Energy report (published early 2010) summarizing cooling options and their associated costs for Concentrated Solar Power (CSP) technologies, it was found that the water requirement of some of the CSP technologies is equal to, if not slightly higher than that of nuclear and coal-fired power plants.

For instance, parabolic trough technology requires large amounts of water to condense steam, make up for the steam cycle, and wash mirrors. Current commercial technologies of water-cooled parabolic trough plant consume approximately 3m3/MWh, of which 2 percent is used for mirror washing. For example, a 100MW parabolic trough power plant will need 300 m3/hour, 4,800 m3/day and 1,752,000 m3/year. This means a very large amount of water is required, which may create a challenge to the application of CSP power plants in the GCC region where water resources are very scarce. However, CSP power plants with dry cooling technologies are being developed. The efficiency of dry cooling depends on the maximum temperature of the fluid. That is why there is ongoing research on high temperature receptors (800C Metal-1200C Ceramic).

### *Summary*

Fig. 5 presents a comparison between different solar technologies based on different parameters and characteristics. The different color nuances indicate the degree of adaptation of the specific technology with some important parameters. Dark green color indicates the specific technology is an application and red color means that it has critical drawbacks.

**Fig. 5: Comparison of solar technologies application in the GCC region**




Source: Azur Solar

Considering the GCC region's specific climatic conditions, it is clear from Fig. 5 that CPV technology may be considered as one of the most promising solar electricity technologies for small, medium and large solar power plants in this region. Of course, technology is continuously developing and some of these colors may change in the future.

## 3. Barriers, Incentives and Challenges

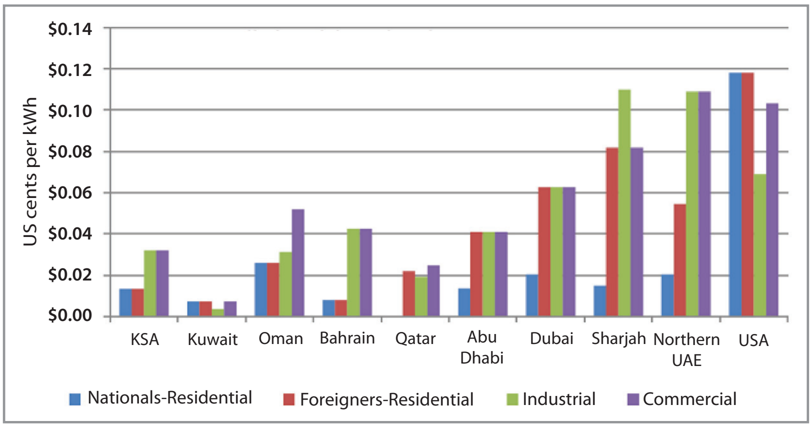
### *Barriers & Incentives*

The GCC countries are still lagging behind in the application of renewables, but they have started picking up recently. The reasons behind this lag are the lack of sufficient awareness among people and especially decision makers, relatively initial high investment, fear of change from conventional and secure energy resources to intermittent and uncertain renewable and clean energy sources, lack of clear regulations and incentives, lack of industrial motivation, lack of expertise and know-how, and also lack of sufficient information about the potential and appropriate technologies to be used. It is only recently that some countries have started seriously investigating their potential in solar energy. They have published some of their research work[1] and developed maps showing optimum siting of solar energy power plants.

1. A. Al-Badi, A. Malik and A. Gastli, "Assessment of Renewable Energy Resources Potential in Oman and Identification of Barrier to their Significant Utilization," *Renewable & Sustainable Energy Reviews* (RSER) 13, no. 9 (December 2009): 2734–2739 (available at http://doi:10.1016/j.rser.2009.06.010). Also refer to all other works cited in the references.

The incentive to adopt renewable energy in the GCC region is mainly driven by climate change obligations, especially after the ratification of Kyoto Protocol by all the GCC countries. Table 2 summarizes the GCC countries' concerns about climate change.

**Fig. 6: Retail electricity prices in the GCC versus the US in 2011**




A second incentive is meeting future energy demand. Indeed, being one of the regions with the highest per capita energy consumption, efforts in the GCC region must also be focused on renewable energy applications and demand-side management (DSM) options. Unfortunately, the heavy energy price subsidies that feature in all the Gulf economies remain a major barrier to any serious renewable energy application and DSM actions. Fig. 6 shows the retail electricity prices in the GCC versus the US in 2011. Notice that all the GCC countries have set relatively cheap prices which encourages more energy consumption and waste.

**Table 2: Climate change concerns in the GCC region**

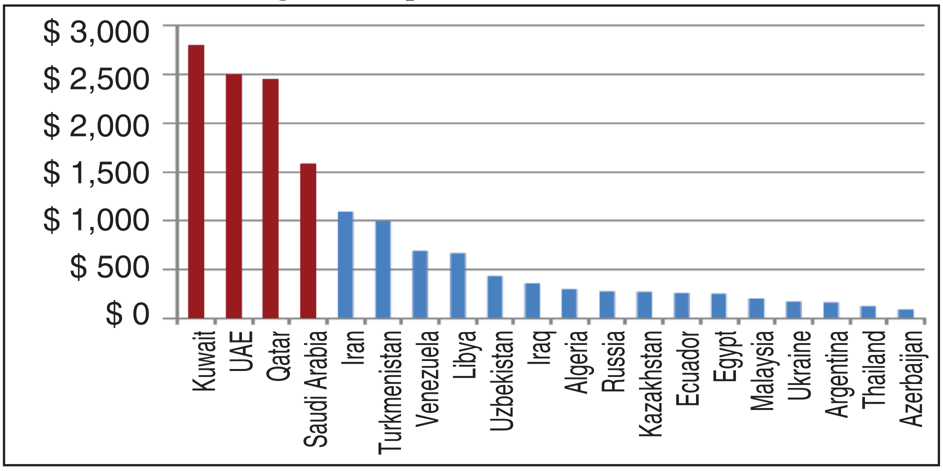
| **Ratification of Kyoto Protocol** | All in 2005 except Bahrain in 2006 |
|---|---|
| **Administrative capacity dealing with climate change issues** | ☐ Bahrain: Public Commission for the Protection of Marine Resources<br>☐ Kuwait: Environment Public Authority<br>☐ Oman: Ministry of Environment & Climate Affairs<br>☐ Qatar: Supreme Council for the Environ ment & Natural Reserves<br>☐ Saudi Arabia: Presidency of Meteorology & Environment<br>☐ UAE: Ministry of Environment & Water Resources |

*Table 2, continued*

| | |
|---|---|
| **Government declared targets** | No targets except Abu Dhabi has decided 7% reduction of CO2 emission using 7% RE by 2020 |
| **Implementation policies** | No clear policies |
| **Large-scale pioneer RE projects** | ☐ Bahrain: World Trade Center<br>☐ Qatar: Energy Center<br>☐ KSA: Solar villages (Sustainable campus of KAUST)<br>☐ Abu Dhabi: Masdar City |
| **Registered CDM projects** | Very few |
| **Potential freedom for environmental NGOs** | Not allowed in most of the countries except in Kuwait where it is allowed but restricted. |
| **Vulnerability to climate change** | High |
| **Oil reserves (BP Survey 2007, if production continues at the rate of 2007)** | ☐ Bahrain: <20years<br>☐ Kuwait: >100years<br>☐ Oman: 21years<br>☐ Qatar: 63years<br>☐ Saudi Arabia: 70years<br>☐ UAE: 92years (Abu Dhabi 95% of production) |
| **Solar energy potential** | Very good opportunities |
| **Potential for wind electricity generation** | ☐ Bahrain, Kuwait, Oman, Qatar: Moderate opportunities<br>☐ Saudi Arabia, UAE: Limited potential |

Besides, Fig. 7 shows that the per capita fossil fuel subsidies in the GCC region are the highest in the world as recorded in 2009.

**Fig. 7: Per capita fossil fuel subsidies**




Source: IEA, 2009

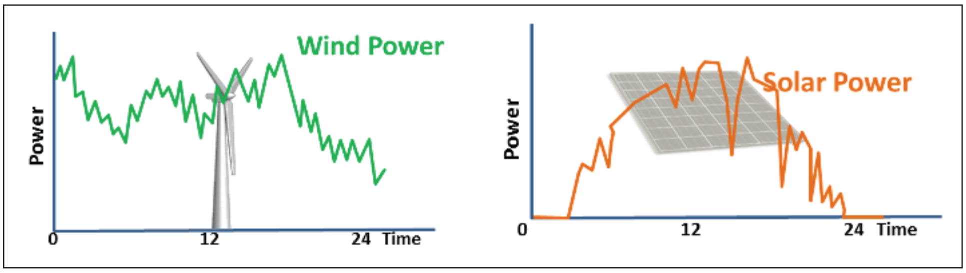
Allowing renewable and conventional energy sources to compete according to market prices would act as an incentive for the utilization and application of renewable energy. However, given the region's political and economic dynamics, the prospect of any comprehensive and immediate energy price rationalization is considered very challenging.

Therefore, it is important to formulate clear roadmaps and policies to help and support the development of the renewable energy sector in the region knowing that there is an implicit additional incentive for developing renewable energy, which is the virtuous cycle in which any fuel saved can be exported increasing overall income. Besides, the progressive infrastructure evolution may help to soften future adjustments due to dwindling resources, as well as lead to sustainable wealth creation for the coming generations.

### *Technical Challenges*

Technological barriers include the challenge of scaling up of immature technologies to commercial level, intermittency and back-up capacity, storage, siting and land use issues. Renewable energy such as wind and solar are known to be variable, but are cyclical and they can be predictable (see Fig. 8).

**Fig. 8: Wind and Solar Energy Intermittency**




While there is a large amount of solar radiation in the GCC region, there are also a lot of problems associated with sand and dust movements and their accumulation on solar panels.[2] This constitutes a major challenge for the implementation of solar energy in the region. Fig. 9 is an illustration of the dust storm effect on Qatar and its capital city Doha.

2. Al-Badi, Malik and Gastli, "Assessment of Renewable Energy Resources Potential in Oman and Identification of Barrier to their Significant Utilization." A. H. Al-Badi, A. Malik and A. Gastli, "Sustainable Energy Usage in Oman — Opportunities and Barriers," *Renewable & Sustainable Energy Reviews* (RSER) 15, no. 8 (October 2011): 3780–3788 (available at http://dx.doi.org/10.1016/j.rser.2011.06.007).

**Fig. 9: Illustration of a typical dust storm in Qatar**

Solar arrays in the GCC region are susceptible to dust and grime collection. Fog and mist contribute to the adhesion of dust on the surface of the collector. The abundance of dust, combined with the occurrence of fog and mist from time to time (see Fig. 10 for illustration), will hamper the output of any solar power station.

**Fig. 10: Samples of dirty PV panels because of accumulated dust deposition**

It is reported that 10 mg/cm2 of dust deposition decreases the power output by more than 90 percent.[3] Also, 4 grams of dust per square meter can reduce a solar panel's efficiency by 40 percent.[4] In regions where rain falls frequently, the

3. A. Gastli, Y. Charabi, and S. Zekri, "GIS-Based Assessment of Combined CSP Electric Power & Seawater Desalination Plant for Duqum-Oman," *Renewable & Sustainable Energy Reviews* (RSER), 14, no. 2 (February 2010): 821–827 (available at http://dx.doi.org/10.1016/j.rser.2009.08.020).
4. A. Gastli and Y. Charabi, "Solar Water Heating Initiative in Oman Energy Saving and Carbon Credits," *Renewable & Sustainable Energy Reviews* (RSER) 15, no. 4 (May 2011): 1851-1856 (available at http://dx.doi.org/10.1016/j.rser.2010.12.015).

most important natural means of cleaning dust accumulation is rain. However, in the GCC region where rain is very scarce, advanced surface coatings and artificial cleaning techniques should be considered and developed. Furthermore, washing with water – the conventional method used to clean solar collector surfaces – may well involve prohibitive costs in the future large-scale implementation in the GCC region. Clearly, even if water (albeit scarce) is available for cleaning purposes, one would like to be able to make a quantitative study of the dust soiling rate in order to minimize the use of cleaning water. On the other hand, if water is not available one would like to be able to study the physical properties of dust on the collector surface to be able to develop dry-cleaning methods as alternatives to water. Research is being conducted to overcome this problem.[5]

The other technical challenges are related to the formation of small networks (called microgrids) of renewable energy distributed generators (DG). They are expected to become a crucial part of the integration of renewable but variable energy sources into the electric grid. However, the uncertainty and variability can be dealt with by switching in fast-acting conventional reserves as needed on the basis of weather forecasts. Energy storage systems may also assist in facilitating smooth or seamless transitions as well as providing high robustness to the local supply.

Microgrids on the generation side may also synergically complement Smart Meter Management on the distribution end, configuring altogether local Smartgrids.

On the other hand, for many years, utilities have been using Direct Load Control (DLC) to unilaterally shed remote customer loads and to provide critical peak load reduction. By reducing the need for higher generation capacity during peak demand periods, load control provides significant cost savings for utilities. Sometimes, however, some customers in the region become upset when they are completely disconnected from the electricity grid during shedding time. This load shedding is more regulated in western countries. For instance, in Europe there are important compensations for load shedding availability, which are negotiated with big energy consumers (such as scrap foundries and aluminum smelters). These compensations

5. A. Gastli and Y. Charabi, "Solar Electricity Prospects in Oman Using GIS-Based Solar Radiation Maps," *Renewable & Sustainable Energy Reviews* (RSER) 14, no. 2 (February 2010): 790–797 (available at http://dx.doi.org/10.1016/j.rser.2009.08.018); Y. Charabi and A. Gastli, "PV Site Suitability Analysis using GIS-Based Spatial Fuzzy Multi-Criteria Evaluation," Renewable Energy 36, no. 9, (September 2011): 2554-2561 (available at http://dx.doi.org/10.1016/j.renene.2010.10.037); Y. Charabi and A. Gastli, "Spatio-Temporal Assessment of Dust Risk Maps for Solar Energy Systems Using Proxy Data," *Renewable Energy* 44 (August 2012): 23–31 (available at http://dx.doi.org/10.1016/j.renene.2011.12.005); Y. Charabi and A. Gastli, "Integration of Temperature and Dust Effects in Siting Large PV Power Plant in Hot Arid Area," *Renewable Energy* 57 (2013): 635-644, (available at http://dx.doi.org/10.1016/j.renene.2013.02.031);

amount to about 750 million Euros in Spain and very rarely is this availability used. Therefore, they are profitable measures for these companies that effectively end up with a subsidized electricity bill. The fear of change linked to greater reliance upon variable renewable energy resources had initially created an obstacle to widespread renewable energy implementation in the region. That is now changing as many utilities launch comprehensive programs and make significant grid investments to lower the costs of integrating renewable generation at the transmission, distribution, and residential levels.

**Fig. 11: Integration of Renewable Energy into the grid**


It is now obvious that there is an urgent need to transform the current electricity system to meet future energy demand and reduce Greenhouse Gas Emissions. So we need a modern, smart and intelligent grid which can respond to all these challenges presented earlier (see Fig. 11). The Smart Grid integrates advanced sensing technologies, control and automation methods, and communication systems. It requires real-time analytic engines able to analyze the network, determine the current state and condition of the system, predict what may happen, and develop a plan. These engines receive data from the utility and outside parties such as weather services through an Advanced Metering Infrastructure (AMI).

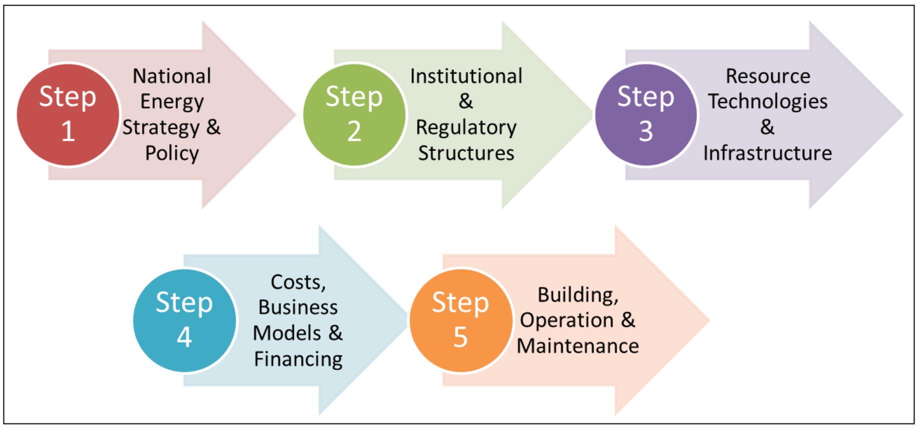
Renewable energy sources, load management, and smart appliances will contribute to more efficient management of energy resources, while at the same time reducing GHG emissions. Appliance manufacturers have been working closely with utilities and other technology vendors to test and pilot various capabilities enabled by smart appliances.

## 4. Recommendations

Awareness is building up very quickly and noticeably in the region. Know-how is being developed locally by academia and industry. Regulations are being drafted. Incentives are being promoted (e.g., CDM). Networking is being encouraged between different parties involved in the sector. (e.g., EU-GCC Clean Energy Network). Smart grid pilot projects have also started in different countries of the GCC region.

All these factors will contribute further to the development of renewable energy applications and their integration into the electric grid. However, clear roadmaps are essential to ensure smooth progress toward the efficient development and integration of renewables into the GCC grid. Therefore, for each potential renewable energy resource and technology, it is recommended that each GCC country's readiness for both on- and off-grid electricity generation and consumption be assessed. For each renewable energy resource and technology, we need to follow the steps shown in Fig 12.

**Fig. 12: Recommended steps to follow during the analysis of the GCC region's readiness for Renewable Energy implementation and integration into the grid**



For each of the recommended steps in Fig. 12, we need to investigate the current status, issues to be resolved, opportunities and actions, and capacity building needs. The recommended process can be summarized as follows:

- *Action:* Define the action
- *Resource-service pair(s):* On-grid? Off-grid? Required resources?
- *Description:* Describe the implementation of the action
- *Actors:* Define the key actors and stakeholders
- *Timing:* Define a timeframe and/or deadline for the action
- *Key for success:* List the main contributors to the success of the implementation of the action

As mentioned in section 2 of this paper, the GCC region has a unique opportunity to bind renewable energy in a virtuous cycle that could help maximize the overall income from energy resources and allow the progressive construction of flexible, but modern and robust power networks. In addition to the previously mentioned roadmaps, a common long-term perspective and solid foundations in infrastructure, knowledge, and regulations would be desirable in order to build an energy system that keeps developing organically and consistently in the future.

Regarding infrastructure, widely interconnected transmission systems and fluid communication among their operators are always the best option to accommodate, in large balancing areas, different generation technologies to the load requirements. Renewables are variable, but also cyclical, predictable to a certain extent, and geographically distributed. Integrating them though coordinated control centers minimizes the need for backup conventional generation. In isolated areas where weak or no power lines are available, microgrids could be competitive solutions. Advanced control and communication systems may help integrate different generation technologies and maintain good power quality at a local level, where renewables reduce fuel consumption and storage systems may provide high efficiency and stability.

The complex and evolutionary nature of modern power systems demands continuous adaptation and integration of technologies. Therefore, a sound local knowledge base is indispensable to keep the pace. Universities must set the concepts, and applied technology centers should support common industrial needs to facilitate a dynamic and competitive market. Test facilities which may help technology development and verification of local requirements are of particular importance for future development. Advanced forecasting of renewable resources and modeling are key capabilities for maintaining acceptable grid behavior. Reactive power/voltage control, LVRT compliance, active power/frequency control and multilevel control of renewable energy plants are all important research topics for successful clustering of technologies.

Energy is the life blood of any society and a major concern for all governments. Thus, governments should take responsibility to set clear rules and standards that may facilitate the decisions needed. Such a framework should be integrated with dynamic policies which should be based on good technical advice and foresight. An optimum energy mix should always be pursued and technology barriers could be overcome by setting up the appropriate connection requirements, operational procedures, and adaptative financial incentives.

## Conclusion

Solar energy has the highest renewable energy potential in the GCC region, followed by wind energy. An analysis of different solar technologies has concluded that solar thermal applications such as CSP should be further researched for hot and arid climates, as most current power plant implementations rely on heavy water consumption for achieving good efficiencies. A comparison between PV technologies showed that the CPV can be a promising technology for the GCC region because of its high efficiency and suitable operation in hot climates.

The main barriers facing the application and integration of renewables into the GCC grid are the lack of awareness, accurate historical climate data, and clear policies and regulatory frameworks. Technological barriers such as dust and high temperature effects are being investigated by many researchers in the region.

It is recommended that the integration of renewables in the grid must be accompanied by the conversion of the current conventional grid into a smart grid. For that, well-defined roadmaps for the smart grid and renewables must be developed urgently by each GCC country. In addition, universities must contribute to knowledge and capacity building through tailored educational and research programs. Besides, applied technology centers should support common industrial needs to facilitate a dynamic and competitive market. Finally, professional networks (such as the EU-GCC Clean Energy Network) are expected to play an important role in sharing good practice among the different stakeholders and members.

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