GENI Global Energy Network Institute

Saudi Arabia Beyond Oil-Based Economy

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List of Abbreviations

AC – Alternating current

CSP – Concentrated Solar Power

DLR – German Aerospace Center

DNI – Direct Normal Irradiance

GCC – Gulf Cooperation Council

GCCIA – Gulf Cooperation Council Interconnection Authority

GHI – Global Horizontal Irradiance

HVDC – High-voltage direct current

K.A.CARE – King Abdullah City for Atomic and Renewable Energy

PM – Particulate matter

REACCESS – Risk of Energy Availability: Common Corridors for Europe Supply Security

TREC – Trans-Mediterranean Renewable Energy Cooperation

Abstract

With one quarter of the world's known oil reserve positioned in Saudi Arabia, the Saudis hold a superpower status in the global energy industry. Today, this superpower is being challenged by its own soul. Its domestic demand; the demand of oil and gas in Saudi Arabia is growing at 7% per year[1]. Currently, the country consumes a quarter of its oil production. Assuming similar population growth and technology with similar consumption patterns, this indicates that on a business-as-usual path, the country will become an oil importer by 2038, as shown in Figure 1.

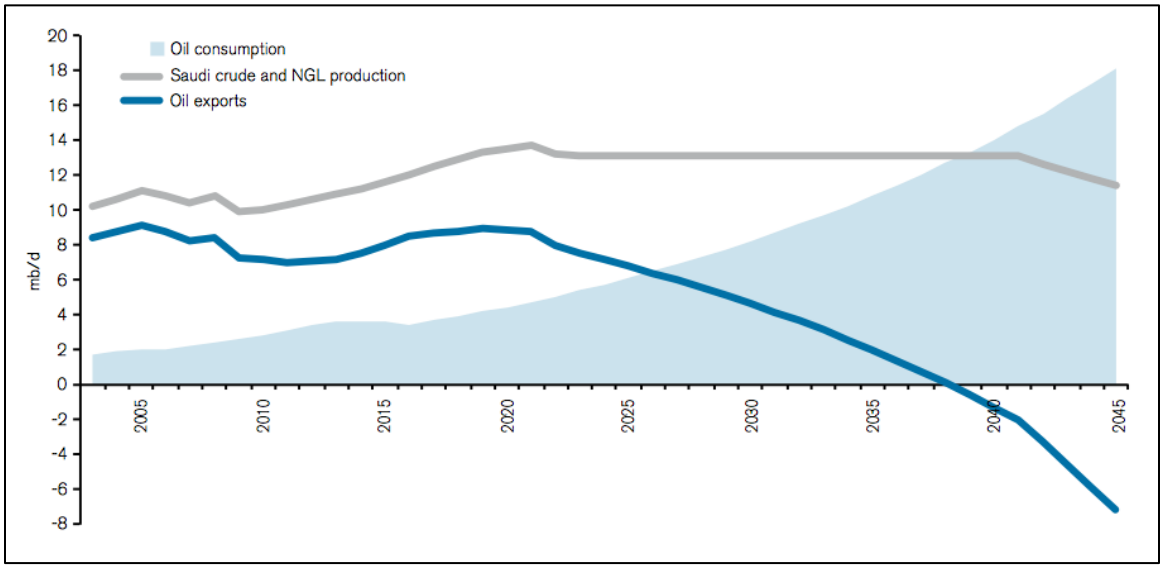

Figure 1: Oil reserve balance for Saudi Arabia on a business-as-usual path.
Source: Chatham House research 2010.

This report summarizes the negative impacts of the country's dependency on fossil fuels to fulfill the domestic demand of energy. In addition, it offers an alternative model that sustains the limited natural resources in the kingdom, supports the strategic & economic goals of the kingdom, and offers the kingdom the opportunity to dominate a new industry.

[1] Lahn, G. & Stevens, P. (2011) *Burning Oil to Keep Cool, The Hidden Energy Crisis in Saudi Arabia*, Chatham House.

1. Impact of the Current Industrial Development Strategy

Today, Saudi Arabia leads the Gulf Cooperation Council (GCC) countries in its CO_2 emissions and is ranked fourteen-worldwide. [2] This is the result of the conventional electricity generating methods adopted over years by the kingdom. As of 2011, around 50% of CO_2 in the country was driven by the power and electricity sector as demonstrated in Figure 2.

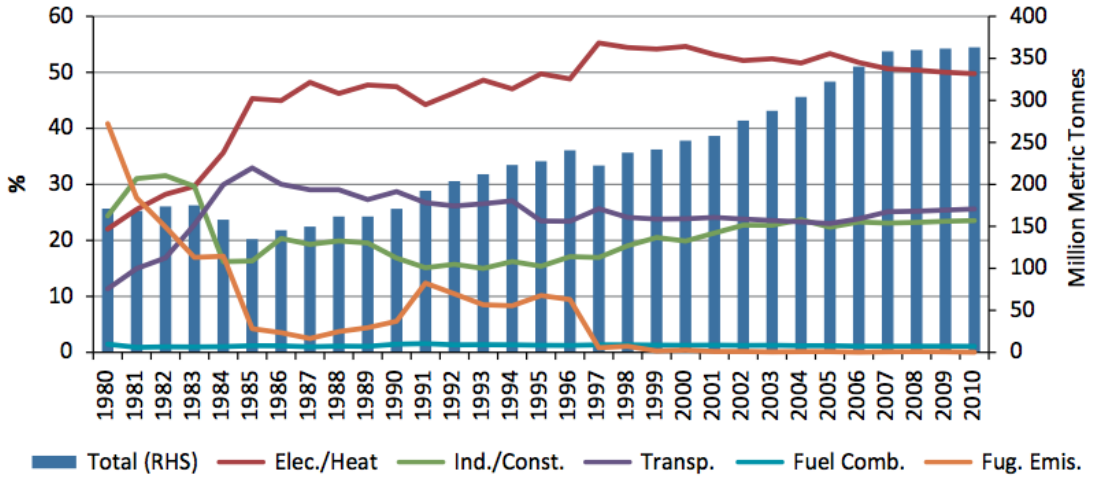

Figure 2: CO_2 emissions in Saudi Arabia by Sector, 1980-2010.
Source: Energy and Environment in Saudi Arabia: Concerns & Opportunities by Named Taher, Bandar Al-Hajjar.

For this reason, the relation between the emission of greenhouse gases such asCO_2, SO_2 and NO_2 has increased as electricity consumption has increased, see figure 3 below). This creates a tremendous pressure on the environmental protection standards set by the Presidency of Meteorology and Environment. This agency restricts the average annual inhalable suspended particulate (PM) concentration in any site to 80 µg/m3 per year[3]. This has already been exceeded, as the PM concentration in Saudi Arabia is about 113 µg/m3 per year on a weighted average for urban population.[4]

- [2] Almasoud, A.H. & Gandayh, H.M., (2014), " Future of Solar Energy in Saudi Arabia," *Journal of King Saud University – Engineering Sciences*

[3] Presidency of Meteorology and Environment,(2013) *Environmental Protection Standards*. Kingdom of Saudi Arabia.

[4] El-Husseini , et al. (2009)"Pollution Is a Regional Scourge." *A New Source of Power The Potential for Renewable Energy in the MENA Region*, Booz & Co..

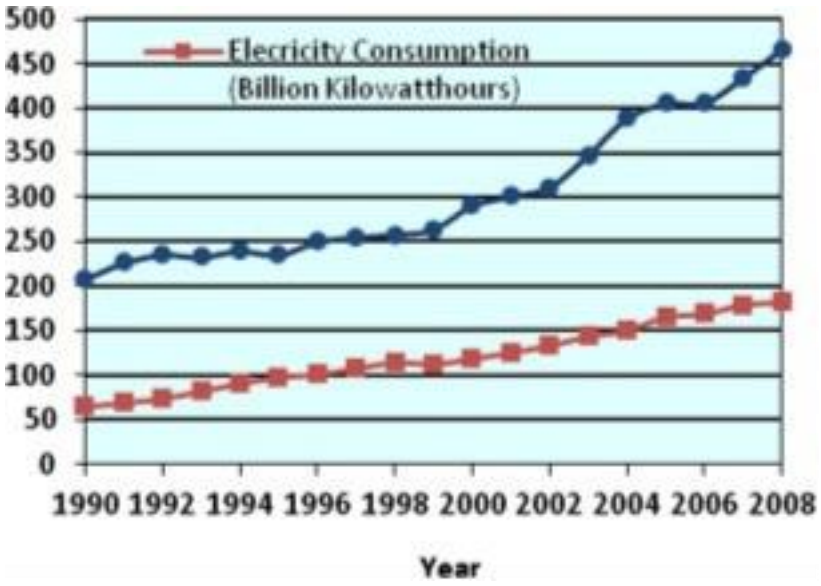

Figure 3: CO_2 emissions versus electricity consumption Saudi Arabia.
Source: *Almasoud, A.H. & Gandayh, H.M., (2014), "*Environmenal and Health Issues: Future of Solar Energy in Saudi Arabia*," Journal of King Saud University – Engineering Sciences*

The PM level introduced by these activities imposes negative impacts on the public health in Saudi Arabia. In the short-term, the exposure to PM pollution lead to numerous significant health problems including heart attack, premature death, aggravated asthma, and chronic bronchitis[5]. In the long-term, such exposure increases the risk of lung cancer. In 1998 the California Air Resource Board reported that in San Francisco bay area; 80% of total cancer risk due toxic air, was caused by exposure to diesel PM. [5] Adopting alternative power generation strategies, ones that take advantage of the sustainable options in the kingdom, will play a crucial role in minimizing the consequences of the rapid development plans in the kingdom.

[5] "Particulate Matter." Bay Area Air Quality Management District. Retrieved on January 05, 2015.

2. Potential of Alternative Power Generation Systems

The opportunities to adopt solar power in Saudi Arabia are enormous. The solar potential offers the kingdom the chance of becoming one of the highest energy-superior countries in the world. Recognizing this potential, the Saudi government established the King Abdullah City for Atomic and Renewable Energy (K.A.CARE) in April 17, 2010, with the mission of transforming this potential into a commercially & environmentally feasible option. K.A.CARE's current goal is to generate one third of the national demand of electricity from renewable energy by 2030; this would be equivalent to 54 gigawatts. [6]

> *Not only could Saudi Arabia power its whole country with solar energy, it could even generate enough solar energy covering the global yearly electricity needs using just a relative small part of its desert area.*
>
> ~ Edwin Koot, CEO, Solar Plaza
>
> Desert Solar in Saudi Arabia Conference[7]

The kingdom has the potential to go beyond K.A.CARE's overall target of 41 gigawatts from solar energy by 2030. Analyzing solar radiation and sunshine duration in the country explains how such a claim can be turned into a reality. Figure 4 presents the global solar radiation on horizontal surface (H) and the long-term average value of sunshine duration (S) for 41 locations in the kingdom. This data shows that even in the northern region, the values obtained are exceed what is available in European cities that have led the way in solar power production.

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[6] , Stryn, C. & Norman, M., (2012) *Saudi Arabia: The Future Solar Leader*, Dubai: Chadbourne & Parke, LLP

[7] Saudi Arabian Solar Energy Association, (2014*) Desert Solar in Saudi Arabia Conference*.

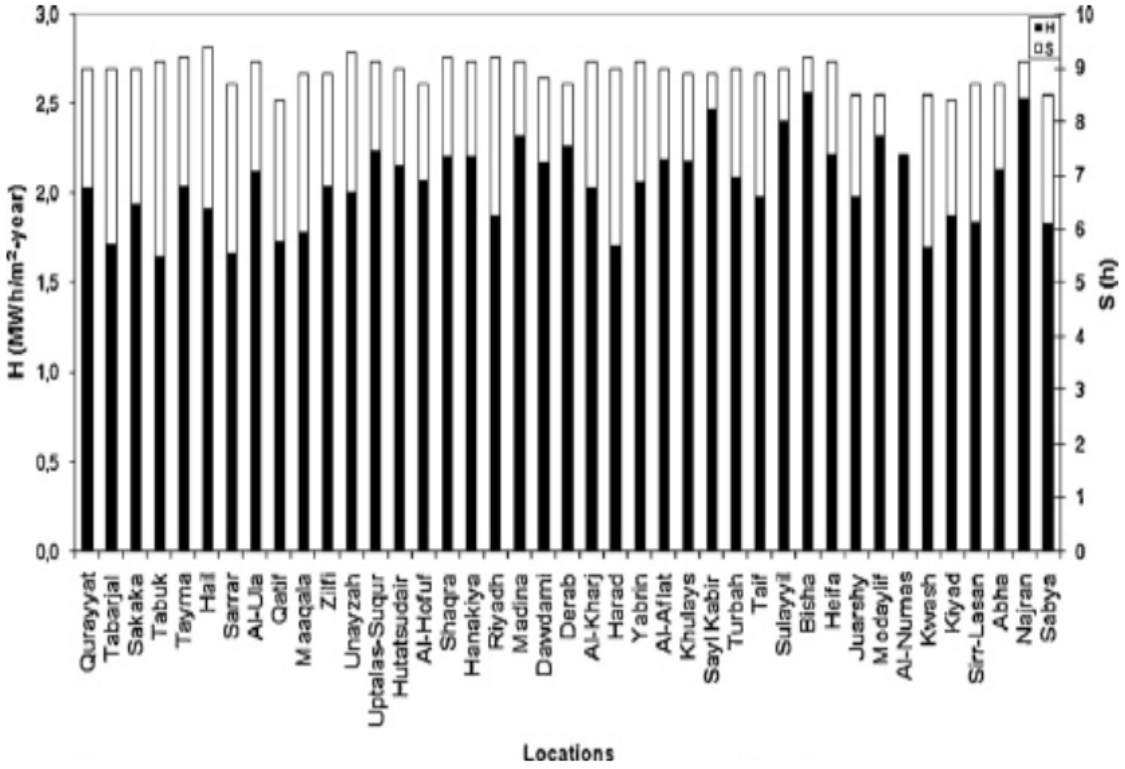

Figure 4: Global Solar Radiation and mean value of sunshine duration in 41 locations in Saudi Arabia.
Source: Rehman, S., Bader, M & , Al-Moallem, S. (2007) **"**Cost of solar energy generated using PV panels.*" Renewable and Sustainable Energy Reviews*

Currently, Germany leads the world with 35 gigawatts of solar installed capacity[8]. This is the first stage of a federal government strategy, with a target of 66 gigawatts by 2030[9]. As can be seen by Germany's GHI map, the average solar irradiation in Germany is somewhere between 980 - 1200 kWh/m^2. This demonstrates that the country is limited to the solar PV technology.

In contrast, Saudi Arabia has the capacity to invest enormously as well in the technology of concentrated solar power (CSP). The economic promise of the significant resources of the direct normal irradiation (DNI) surpasses the challenges imposed by the high DNI level and dust loadings in the kingdom. For the PV cell, a high DNI and extreme ambient temperatures might reduce the output power by up to 26.4%, utilizing dry air cooling technologies overcome this major technical challenge.[9]

Similarly, the feasibility of CSP technologies in Saudi Arabia goes beyond the applications of electricity generation. The low level of efficiency required by concentrated reflectors to achieve the desired evaporation process in multi effect distillation unit demonstrates the competitive advantage of solar thermal plants over the co-generation or the conventional plants.[10]

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[8] Solar Energy Industry Association (2014) Solar Energy Support in Germany: A Closer Look..
[9]. Global Potential of Concentrating Solar Power. Retrieved on January 14, 2015
10 Brasas, A., et al., (2012) Opportunities and Challenges of Solar Energy in Saudi Arabia.

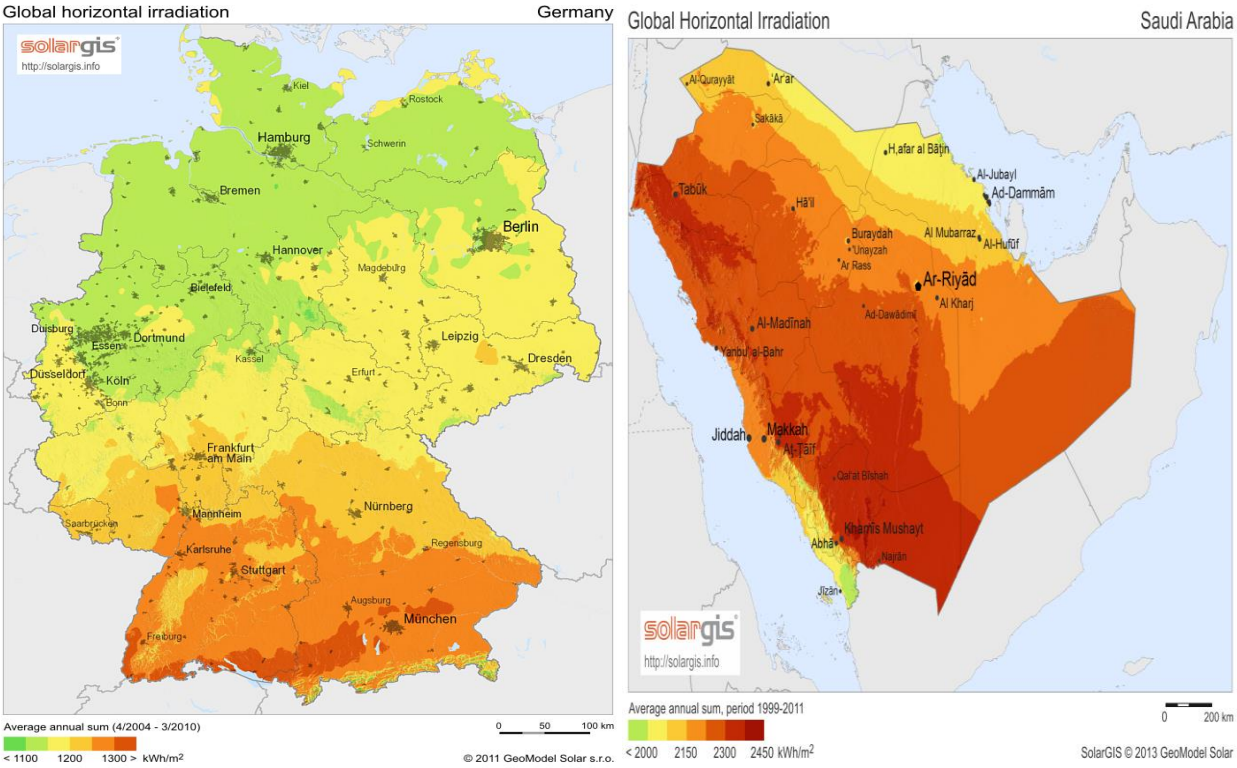

Figure 5: Saudi Arabia versus Germany global horizontal irradiation data.
Source: Solar GIS maps of Global horizontal irradiation

The map below demonstrates the significant potential of the location of the Arabian Peninsula, which receives an annual solar irradiance higher than 2000 kWh/m2/y. The data provided in this map by the European project REACCESS excludes covered area, such as forests, gas fields, mines and agriculture fields.

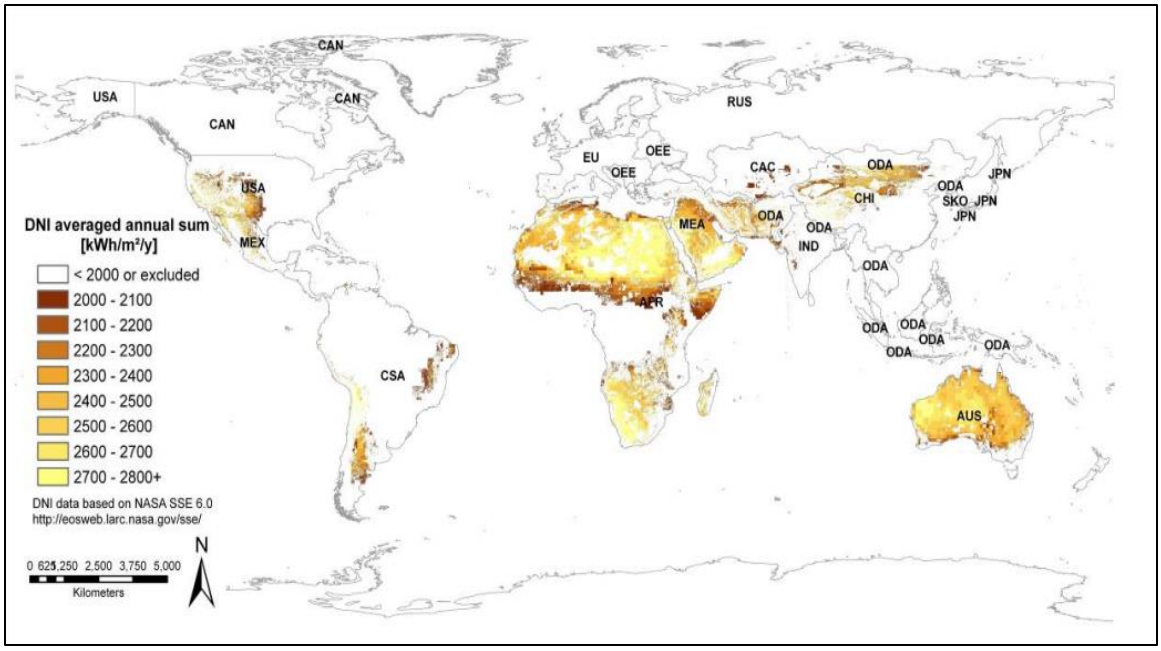

Figure 6: Map of direct normal irradiation as described by EU-project REACCESS.
Source: Trieb, F, et. al (2009) *Global Potential of Concentrating Solar Power*

3. Supergrid Deployment for Alternative Energy Scenario

As Saudi Arabia is pressured to diversify its economy, formation of energy corridors to export clean energy will offer the region the economic shield against a major global shift from fossil fuels. Utilizing high voltage corridors will enable the kingdom to link energy potential areas not in close proximity to load centers or future consumptions with existing power grids. This technology will offer the kingdom the ability to transmit high levels of controlled power over large distance. This will give the Saudis the chance to connect with the rest of GCC countries; achieve an abundance of sustainable energy resources; and rationalize the dream of exporting solar energy. The visibility of this concept, utilizing high voltage direct current (HVDC) technology to export clean electricity, has been well addressed through joint worldwide research efforts described in the following pages

3.1 Trans-Mediterranean Renewable Energy Cooperation (TREC)

The TRANS-CSP study conducted by the German Aerospace Center (DLR) analyzed the idea of interconnecting the electricity grids of the Middle East, North Africa, and Europe for a sustainable supply of energy.[10] Figure 7, below, illustrates the potential of such an interconnection.

[10] Characterization of Solar Electricity Import Corridors from MENA to Europe: Potential, Infrastructure and Cost, 2009, 2. Retrieved on January 14, 2015.

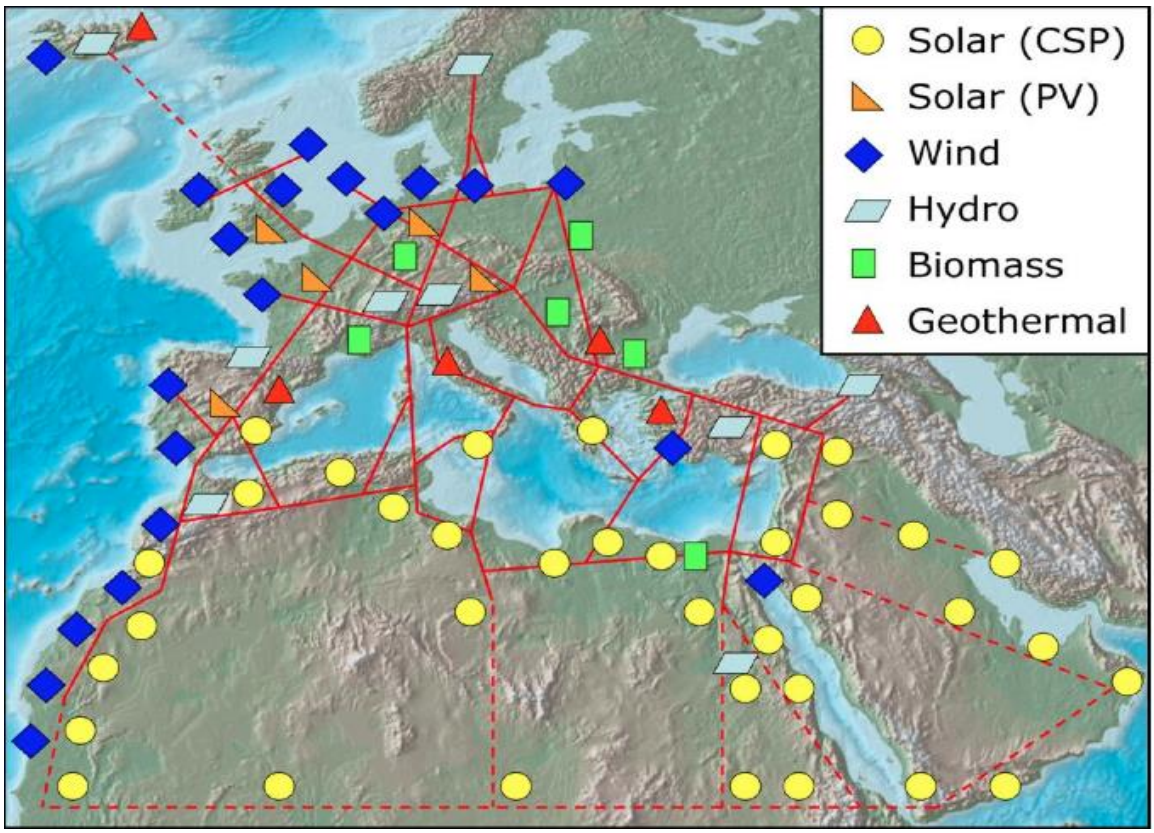

Figure 7: Map of suggested infrastructure of Europe supergrid with the Middle East & North Africa. Source: TREC Clean Power From Desert by Gerhard Knies.

This study demonstrated the potential and benefits of importing solar energy from the Middle East & North Africa (MENA). In a time span of only 15 years, adopting a similar pattern of sustainable energy mix will offer an economic advantage over the conventional power generation strategy. Additionally, contrary to the conventional interconnected alternating current (AC) grids, HVDC transmission can minimize loss in the transported electricity to 10%.

3.2 Gulf Cooperation Council Interconnection Authority (GCCIA)

Initiated in July 2001, the goal of the GCCIA is to interconnect the power grids between Saudi Arabia, Bahrain, Kuwait, Oman, Qatar, and the United Arab Emirates (UAE).[11] The technical feasibility of HVDC links to interconnect the power grids between these six countries was evaluated and confirmed through the effort of King Fahd University of Petroleum and Minerals, Bahrain Electricity & Water Authority, and the Kuwait Institute for Scientific Research. The economic viability was also evaluated through Hydro Quebec and SNC‐Lavalin of Canada. Figure 8 describes the geographical map for the interconnection project linking the GCC states.

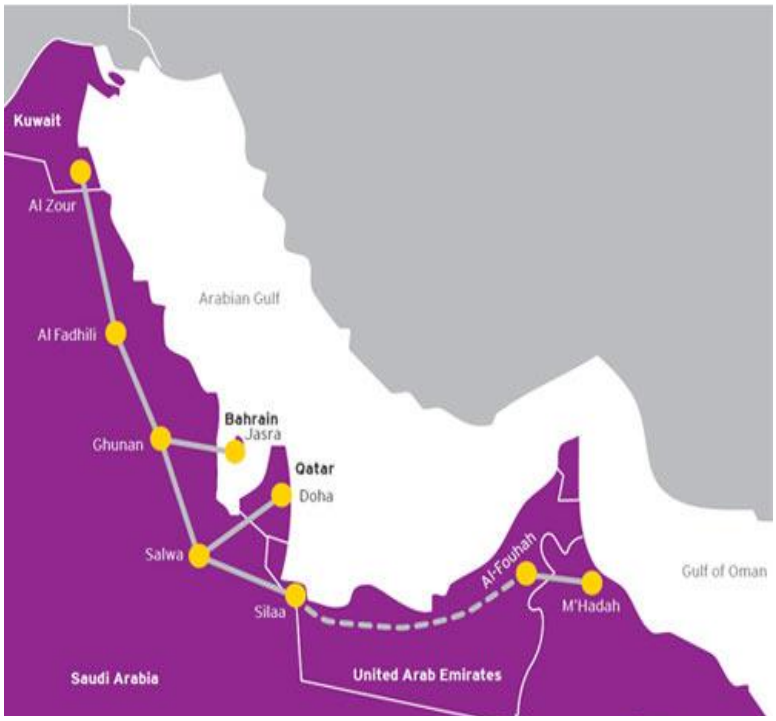

Figure 8: Geographical map of the interconnection project linking the GCC states. **Source:** Gulf Cooperation Council Interconnection Authority.

Through a three phases plan, the project began by interconnecting Saudi Arabia, Qatar, Kuwait, and Bahrain. The second and third phases will enable the integration of the UAE and Oman with the rest of the GCC countries.[12] The limitation of the GCC grid interconnection plan will restrict the GCC countries to a regional power market exchange. This limitation will prevent the region from taking complete advantage of its optimum location for concentrating solar thermal power stations. This sustainable power

[11] History of the GCC Grid." *GCC Interconnection Grid: Transforming the GCC Power Sector into a Major Energy Trading Market*

[12] Gulf Cooperation Council Interconnection Authority..

option offers a superior advantage in the future electricity market for several reasons:[13] It has:

- The ability to satisfy all load segments.
- A low level of transmission loses: 10 – 15%
- A low importing costs: around 0.05 €2000/kWh
- A superior spinning reserve.

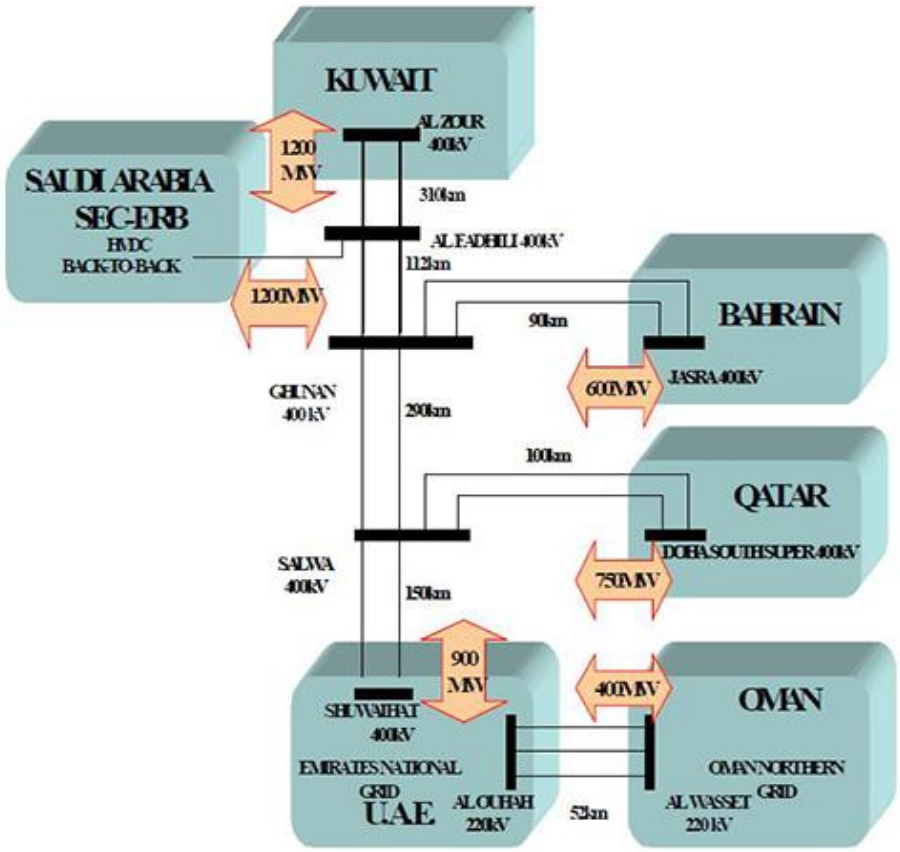

Figure 9: Electrical map of the interconnection project linking the GCC states.
Source: Gulf Cooperation Council Interconnection Authority.

[13] Characterisation of Solar Electricity Import Corridors from MENA to Europe: Potential, Infrastructure and Cost, 2009, 2.

4. Conclusions

As more of the developing countries introduce policies similar to feed-in tariffs in Germany, the future of the current energy leaders is unpromising. These regulations accompanied with future global carbon tax policies will ensure that carbon producers are penalized. It will also achieve a long-term security to the alternative energy industry.

For Saudis, these environmental guidelines coupled with the domestic demand for oil and gas introduces a critical challenge to the government's rapid development plans. On a business-as-usual path, the country will be at risk of becoming an energy importer by 2038. Fulfillment of the government mission to integrate alternative source of energy in power generation and water desalination will not minimize the country's complete dependency on oil revenue. The threat of this dependency should urge the country to thoroughly appreciate its geographical location in the center of the so-called Sun Belt. These validated potentials should serve as a proof of the country capacity to lead a different energy market.

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