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*Research Article*

# The Prospect of Solar Energy in the Development of Power Stations in the State of Kuwait

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Over the years, the production capacity for power generation has not been able to keep pace with the surge in electricity demand in the oil-rich State of Kuwait. To expand its power generation capacity, Kuwait's strategic energy plans focus on constructing gas turbine and fuel oil stations. This paper aimed to evaluate the prospect of photovoltaic solar energy (PV) in generating electricity as an alternative to decrease dependency on combined cycle gas turbine (CCGT) power stations. It applies the LCOE framework to evaluate the economic feasibility of installing a 100 MW PV and CCGT power stations in Kuwait. The results indicate that under the assumption of 5% interest rate, the estimated LCOE of PV station ($0.19/kWh) is unfeasible in comparison to the generation cost of gas turbine station ($0.11/kWh). However, the analysis has emphasized that evaluation of future electricity generation plans must not be limited to the LCOE criteria and should incorporate the following factors: the effect of natural gas supply constraints on the production of gas turbine plants, the environmental concerns of $CO_2$ emissions, the peak load demand, and the domestic energy balance mix. The paper concludes that once these factors are addressed properly, the prospect of PV power stations becomes relatively feasible.

## 1. Introduction

Kuwait is a small rich economy with abundance reserves in fossil fuels. (The GDP in 2010 was around $136.5 billion, and per capita income was estimated to be $48,900, one of the highest in the world. The economy depends heavily on oil exports and revenues. Oil accounts for 50% of GDP, 95% of exports, and 80% of government income.) By the end of 2010, it was estimated that Kuwait had proven crude oil reserves of 104 billion barrels (9% of total world oil reserves), and its reserves of natural gas were around 63 trillion cubic feet (1% of global proved reserves). Kuwait is a major oil exporter (about 2.4 million barrels per day) and a vital member of OPEC. It also produces a modest volume of dry natural gas, approximately 449 billion cubic feet [1]. This small country consumes a massive amount of its natural hydrocarbon resources to meet the rising local demand for electrical power. Since the inception of modern Kuwait in 1961, total consumption of electricity has increased significantly over the years. Total consumption of electricity has increased from 380 million kWh in 1960 to 46,601 million kWh in 2009. The accelerated rise in total electricity consumption was due mainly to the growth of both the per capita consumption and population. In particular, over the period (2000–2009) the average annual growth rate of per capita consumption of electricity was around 6.9% per annum, which is higher than the population average growth rate of 3.8% [2]. The high growth in demand for electricity and water was driven by several factors, mainly

(i) growth of the economic activities facilitated by high oil revenues,

(ii) high growth rate of population (due mainly to influx of expatriate labor),

(iii) improvements of life standards and a greater penetration of electricity appliances,

(iv) sustained low electricity and water prices,

(v) the summer desert hot weather is a key driving force behind demand for electricity. High temperature has a strong influence on the demand profile and resulted in the widespread use of air-conditioning systems directly fed by electricity.

Among these factors, low electricity and water prices sustained by government electricity and water subsidy program are the most influential. The program was established in 1966 with the aim of elevating the public social welfare by heavily subsidizing more than 95% of the electricity selling price. Over this period, consumers were only liable to pay the minimum of 2 Fills/kWh (less than \$0.01 or 1 Cent) out of electricity average generation cost estimated 34 Fills/kWh (\$0.12). This public policy has resulted in inefficient utilization and huge waste of energy resources. More importantly, it has enforced the behavior of negligent consumption of electricity by most of the consumers [3].

## 2. The Power Industry in Kuwait

The Ministry of Electricity and Water (MEW) is the sole provider of electricity and water in Kuwait (pure monopoly). Therefore, electricity generation industry is fully state-owned and is vertically integrated with the oil industry. Fuel for the production of electricity is provided by the Kuwait Petroleum Corporation (KPC) to the MEW at no charge. In 2009, Kuwait had an installed capacity of 11.6 GW of electricity production units and 423.1 MIGD (1.9 million $m^3$/day) of water desalination capacity. In order to face growing demand of electricity and water, a series of plants are already under construction or planning.

In 2009, heavy fuel oil represented more than 55% of total fuel used by power plants (in terms of equivalent oil energy). Heavy fuel oil remains the least expensive fossil fuel in Kuwait's current fuel mix. With the recent construction of natural gas power plants, the share of natural gas in Kuwait's fuel mix increased and reached more than 25% in 2008. Some gas turbines are adapted to run on different fossil fuels (mainly gasoil), though natural gas is usually given priority as it remains cheaper than other alternatives. However, constraints on supply of natural gas have limited its share of the fuel mix [4].

## 3. Justification of the Study

A number of relatively old studies have analyzed the demand side of electricity consumption in Kuwait [3, 5, 6]. These studies have emphasized the importance of reforming the electricity and water subsidy program by imposing higher selling prices for the residential and industrial sectors. Initiatives to raise these prices were met with strong opposition from the Kuwaiti parliament. This has forced the government to limit its efforts of curbing electricity demand to large-scale awareness campaigns. More importantly, as demand for electricity has been increasing, the capacity for power generation has not been able to keep pace with the surge in demand. Hence, the supply side of electricity (i.e. production capacity) has not been addressed properly by scientific research. Specifically, the shortage of power supply during summer season (peak load demand) contributes significantly to the dilemma of supply planning and development. To face that, the government is planning to build new power plants, with focus on gas turbine. The energy requirements for these plants were manifested in the 2020 national energy strategy as follows [7].

(i) Increase the refining capacities by 50% over the next 5 years.

(ii) Double lean gas production so that gas share in Kuwait's energy production can be increased from 20% up to 40%. This should enable Kuwait to become self-sufficient in its reliance on natural gas required for combined cycle gas fired turbine (CCGT) plants.

(iii) Reduce consumption of fuel oil required for the generation of electricity by reheat steam power plants (RHSPP).

Therefore, Kuwait seeks to significantly increase its use of natural gas in electricity generation and water desalination in order to allocate more oil for export. Plans are to increase drilling for natural gas and limit flaring of associated gas by upgrading refining capacities and technologies. This trend emphasizes the government commitment toward increasing fossil fuel production (oil/gas). In the light of abundance of fossil fuel in Kuwait, initiatives for renewable energy sources (RES) and rational use of energy (RUE) were always viewed negatively by the government. However, the domestic and global changes in the energy market are forcing the government to change this view. Presently, the government is exploring initiatives for RES applications, with emphasis on solar and nuclear energy. Hence, it is the purpose of this paper to evaluate and compare the economic feasibility of using different alternatives for electricity production in Kuwait. Specifically, the paper will compare the unit cost of producing electricity (kWh) based on the extensively used indicator of levelized cost of electricity (LCOE) and address its implications in terms of Kuwait's energy mix. Kuwait has sufficient experience in developing both the natural gas fired combined cycle power plant (CCGT) and the reheat steam turbine power plant that uses heavy fuel oil (RHSPP). However, it lacks experience with large solar energy applications. Understanding the economic cost of electricity production under these alternatives should assist and enhance decision makers capabilities in formulating appropriate energy policies.

## 4. The Levelized Cost of Electricity

The essential economic concept for any PV installation is that its cost should be recovered by the useful energy it produces over its lifetime. To begin with, one realizes that there is more to a PV system than just the module. To produce useful power in a commercial power generating application, one must consider the average illumination in the location and the finite lifetime of the PV panels. Issues related to balance of systems (BOSs) cost such as the mounting, wiring installation, and land must be added to the cost of the module itself. Power conditioning (PC) by control circuitry and inverters must be included, as well as operating and maintenance (O&M) costs [10]. When all of these factors are included, the levelized costs of electricity (LCOE) can be estimated form the ratio of the total life cycle cost to the total life time energy production. This model has been used extensively in the analysis of economic feasibility of PV systems [11, 12].

Therefore, LCOE is a valuable financial tool for measuring and comparing the unit costs of different technologies over their energy production life. Given the structure of the electricity market in Kuwait, where production and selling prices are regulated by the government (purely monopolistic market), the LCOE is an excellent measure for cost comparison between different power generation technologies. (In a competitive market, the LCOE may not reflect the investors' true financial costs associated with technological risks, production costs, and uncertain (varying) electricity prices. Assuming constant production costs and selling prices will underestimate the LCOE, hence, the private investor must use a higher discount rate that takes into consideration the variations in the above assumptions.) The LCOE computes the costs of electricity generation based on key inputs on the costs of building and operating a power plant, in addition to the technical parameters of the utilized generation technology. Fixed costs consist mainly of all costs necessary to build an operational power plant including engineering, procurement, and construction. Variable costs include operations and maintenance (wages and operational expenditures), fuel costs (natural gas or heavy fuel oil), and taxes on carbon emissions. The LCOE is based on a discounted cash flow analysis (net present value), and it corresponds to the selling price that equalizes total investment costs (breakeven point) over the project life, under a set of specific assumptions, including a discount rate. It should be emphasized that the same methodology will be used in this paper to estimate the generation costs for both the photovoltaic solar and CCGT technologies.

The LCOE is estimated by the following formula (1):

$$\text{LOCE} = \frac{\sum_{n}^{nf} (\text{VarCost}_n + \text{FixedCost}_n) \times \text{CRF}}{\sum_{n}^{nf} \text{Output}_n \times \text{CRF}}, \quad (1)$$

where the year, operating life of the power plant, variable costs at year $n$; it includes carbon costs in year $n$ for CCGT plant, fixed costs at year $n$, discount factor at year $n$, CRF $= (i \times (1+i)^n)/[(1+i)^{n-1}]$, Discount rate, amount of electricity produced by the power plant in year $n$.

The electricity output is defined by

$$\text{CCGT Plant Output} = \text{Capacity} * \text{Load factor} * 8760, \quad (2)$$

where capacity is available electric capacity in year $n$; load factor is the generic plant load factor of 85%, 8760 is the number of hours in year $n$.

$$\text{PV Plant Output} = \text{Average Annual Insolation} * \text{Model Efficiency} * \text{Station Capacity}, \quad (3)$$

where average insolation/m$^2$/year = 2033 kwh, model efficiency = 10%, station capacity = 1,000,000 m$^2$.

The parameter and assumption for estimating the LCOE for 100 MW PV and CCGT power stations are specified in Table 1.

Table 1: The LCOE for 100 MW PV and CCGT power stations.

| Technology | Photovoltaic | CCGT |
|---|---|---|
| Plant capacity | 100 MW | 100 MW |
| Fuel used | — | Natural gas |
| Cost of fuel at \$50/bb (\$/kWh) | — | 0.08 |
| Investment cost (\$/kWh) | 5,000 | 1,400 |
| O&M cost (\$/kW/yr) | 150 | 35 |
| $CO_2$ emission cost (\$/kWh) | — | 0.024 |
| Efficiency rate | 10% | 50% |
| Load factor | — | 85% |
| Project life | 25 | 30 |
| Duration of construction | 2 | 3 |
| LCOE (\$/kWh) at 5% Interest rate | \$**0.19** | \$**0.11** |
| LCOE (\$/kWh) at 10% Interest rate | \$**0.28** | \$**0.13** |

Sources: International energy agency [8], Ministry of electricity and water in Kuwait [9].

*4.1. Parameters for CCGT Technology.* For the purpose of estimating the LCOE of CCGT plant, the parameters and data stated in Table 1 were assumed based on two important sources: the International Energy Agency Report [8] and data obtained from the Ministry of Electricity and Water in Kuwait regarding the production costs and parameters for current CCGT plants in Kuwait [9, 13]. Specifically, the IEA report presents the main results of the findings of the different studies conducted in 2009 for estimating the costs of generating electricity from nuclear, fossil fuel thermal power and a variety of renewable energy. In most cases considered in the IEA report, the investment (construction) costs for gas fired plants range between 520 and 1,800 US\$/kWh where expenditures are usually spread over 2-3 years. Based on the estimates provided directly by the Ministry of Electricity and Water in Kuwait regarding the average costs of recent and planned CCGT plants, the investment costs in this study were assumed at 1,400 US\$/kWh. The O&M costs of CCGT plants are lower than those of coal or nuclear plants and assumed at 35 US\$/kWh. Natural gas prices were assumed to be equal to crude oil prices on an energy-equivalent basis (BTU parity). This is in line with the IEA assumed prices of 10.3 US\$/MMBtu in European countries within OECD. The variables efficiency and load factor were assumed based on ME&W data. The last variable that plays an important role in estimating the LCOE for the CCGT is the $CO_2$ emission cost, which is assumed at \$30/ton [14]. The $CO_2$ emission factor was assumed at 0.827 ton for each 1 MWh generated (\$0.024/kWh).

*4.2. Parameters for the Photovoltaic Solar Technology.* Kuwait's climate is characterized with harsh sunny desert weather, which makes solar energy the most appropriate among renewable energy sources. Even though the sand storms may lower the average irradiation during the summer season, Kuwait's average yearly irradiation is very high in comparison with countries that are considered among the dominant users of solar energy such as Spain and Germany. A study by The German Aerospace Center rates Kuwait is excellent in its potential for solar energy applications due to the high average in both daily irradiation and ambient temperature [15]. Kuwait yearly solar irradiation is estimated at around 2100–2200 kWh/$m^2$. (Average irradiation refers to global horizontal (on a plane surface), which does not reflect the real situation when applied to real PV systems. When installing a PV system, the objective is to optimize the energy harvesting. Hence, modules are oriented and tilted toward the true south which will result in a higher value of the average annual irradiation collected by the module. The assumption of 2033 kWh/$m^2$ (based on previous studies) is underestimating the value of solar radiation in Kuwait, but it was used as a conservative figure and to adjust for any lost radiation during the sandy season in June and July.) The two most important factors that affect the demand for PV systems are the module cost and efficiency. In this study the parameters used to estimate the LCOE for PV plants were assumed using recent data published by Solarbuz [16].

*4.3. The Choice of the Discount Rate.* The choice of a discount rate is essential for the proper estimation of the feasibility study. Most of the feasibility studies indicate that within the sensitivity analysis framework, the IRR and NPV are most sensitive to variations (changes) in the discount rate. The evaluation of different investment options using discounting can be applied to both the private and the public investments. Within the framework of public investments (such as the case of power sector in Kuwait), the *social discount rate* reflects the cost of the present relative to the future, and sets the limit of the efforts that society is willing to take when comparing different options. A high discount rate reflects a higher weight on the present time relative to the future. On the other hand, the discount rate used by a private business (*private discount rate*) follows a profit maximization logic, which contrasts with a government's social welfare maximization approach. The firm would then invest in projects where the expected return is at least as high as its internally defined level of *average cost of capital* (WACC), and the discount rate is adjusted for the risk based on market data and financial analysis.

Within this context, there is a wide support for the argument that governments should use risk-free rates. This position is supported by the argument that governments invest in a large number of diverse projects and pool a large share of risks. Spreading total risk over all the projects will lead to a negligible size of risk per project. A unique 5% discount rate was considered as a reference in the present study for the following reasons. Based on Kuwait's recent development plan 2009/2010–2013/2014, the government is planning to invest around 90 Billion US$ in different energy projects over the period 2011–2015, including new power plants. Moreover, the Kuwaiti government can secure large amounts of capital through its accumulated savings in the sovereign wealth funds. In short, the central role of the government in balancing the requirements for long-term energy policy indicates a preference for the low discount rate [4]. It should be noted that the LCOE was also estimated at a 10% discount rate in order to verify the impact of high discount rate (private discount rate) on the different computations.

## 5. Analysis of Results

Based on the specified model parameters and choice of interest rate, at 5% and 10% discount rates, the LCOE for CCGT plant is estimated at $0.11/kWh and $0.13/kWh, respectively. The main components of total levelized costs are fuel costs (72%), investment cost (12%), O&M costs (6%), and $CO_2$ emission cost (10%). In regard to the PV plant, and according to the assumed efficiency of 10%, the LCOE for PV solar plant at 5% and 10% discount rates is estimated at $0.19/kWh and $0.28/kWh, respectively. The main components of total levelized costs are investment costs (91%) and O&M costs (9%).

Hence, the estimated results confirm the fact that the generation cost/kWh for a PV station is much higher than that of CCGT station. This is mainly due to the high investment cost of installing a PV system and its low conversion efficiency. The results also reveal that LCOE of PV system is more sensitive to the changes in interest rate than CCGT; this is in line with the expectation that the larger the proportion of PV investment cost in the structure of LCOE (91%), the more sensitive the results will be to the interest rate. In regard to the assumptions made as part of the CCGT LCOE, fuel price (cost) is the main driver of the LCOE for this technology. The discount rate, investment cost, and capacity factor are much less significant determinates. Hence, the CCGT LCOE is more sensitive to changes in fuel price.

The feasibility analysis of power generation should not rely entirely on the LCOE indicators, but also on other technical factors. The supply of natural gas will play a pivotal role in future developments of Kuwait's electricity and water production sector. Under current plans (with Kuwait relying exclusively on fuel oil and gas fired power plants for its electricity generation), it is clear that supply of natural gas and heavy fuel oil (both domestic production and imports) will have to adapt progressively as the demand for electricity increases. The current outlook clearly shows that supply of natural gas will fall short of answering demand for electricity generation around year 2015 (even considering improvements in average efficiency rates) [17], and any supply gaps would be filled using crude oil. Availability of natural gas through local production or LNG imports will determine the extent to which Kuwait can depend on gas-fired turbines to produce electricity. Evaluation of future plans for electricity generation must incorporate the effect of natural gas supply constraints on the ability to produce electricity. Hence, the focus should not be constrained to issues of generation capacity and LCOE indicators.

In addition, the environmental concerns of $CO_2$ emissions and peak load demand are two important factors that must be addressed properly in the process of evaluating the prospects of future power plants. Kuwait is ranked amongst the highest in the Middle East in per capita energy consumption of oil (9.5 toe), almost double the OECD average. In addition, Kuwait is ranked among the highest in the world in per capita $CO_2$ emissions. During the period 1971–2003 $CO_2$ emissions have almost tripled from 23.2 Mt to 58.3 Mt (average annual growth rate of 2.9%) [18]. The harsh arid environment and lack of fresh water justify, to a certain degree, the increased energy consumption for power generation (particularly for air-conditioning). However, as indicated earlier significant part of this consumption is due to inefficient and irrational use of electricity by end users. The environmental effect of energy consumption validates the importance for Kuwait to decrease dependency on fossil fuel toward the utilization of renewable energy.

In Kuwait, initiatives for RES and effective programs for RUE are absent by both the public and private sectors. The large supply of fossil fuel (oil and gas) and the high investment cost of RES justified Kuwait's long history of investments in conventional energy technologies. Therefore, RES have been persistently viewed negatively by decision makers in Kuwait. However, the authorities have overlooked the fact that Kuwait has a relatively modest experience with renewable energy in this region. Within the Gulf region, Kuwait is considered among the pioneers in initiating research in solar energy applications for power generation, desalination, and air-conditioning. Several small capacity solar cooling applications projects were conducted mainly by Kuwait Institute for Scientific Research over the last three decades in some public schools and buildings. Al-Hasan evaluated the stability of the grid system using connected PV system and found that the peak load demand correlates with the maximum incident of solar radiation in Kuwait [19]. Moreover, Doukas indicates that air-conditioning is the largest component of electrical consumption in Kuwait, accounting for more than 70% of peak load demand and 45% of annual electrical consumption [20]. Hence the implementation of PV stations for cooling applications can lower summer peak load electrical demand and $CO_2$ emissions. In planning for future energy mix, decision makers should incorporate these two factors within the context of a strategy for renewable energy.

## 6. Conclusions and Recommendations

Kuwait has one of the highest per capita electricity and water consumption levels in the world. Sustained low prices largely contributed to the increase in per capita electricity consumption in Kuwait. The massive consumption of energy resources is adversely impacting Kuwait's local environment, through the emission of carbon dioxide and other harmful gases. The fact that Kuwait is rated as the third highest per capita $CO_2$ emitter in the world will only worsen its global environmental image. Hence, this study aimed to evaluate the prospect of solar energy in generating electricity as an alternative to decrease dependency on CCGT power stations. The feasibility results indicate clearly that at 5% discount rate, the LCOE for 100 MW CCGT plant ($0.11/kWh) is more feasible than 100 MW PV station ($0.19/kWh). However, LOCE analysis signifies only one part of the whole picture. Taking into account the environmental impact of fossil fuel and the constraints on natural gas supply, Kuwait should actively pursue initiatives for all type of renewable energy, in particular solar (PV) energy. The justification for a shift toward PV solar energy can be summarized in the following.

(1) Kuwait has a decent experience in solar energy research and applications, mainly through the activities of Kuwait Institute for Scientific Research. This experience should be utilized by the government to advance the role of RES in power generation. These actions will be in line with the global trend toward the implementation of clean (green) energy.

(2) Air-conditioning consumes large part of the electrical power generated in Kuwait, particularly the peak load demand during summertime (around 80%). PV solar applications are more suitable and less expensive means for generating electricity for cooling community buildings, large shopping malls, supermarkets, hospitals, theaters, and schools. PV systems utilizing the maximum incident of solar radiation in Kuwait match the peak load during the hot summer period. This will reduce the pressure on fossil power stations to increase their production capacity and load efficiency.

(3) The domestic energy balance mix should be diversified away from fossil fuel. The implementation of PV systems, among other RES's, can lower the consumption of fossil fuel and consequently prolong the life of Kuwait's oil reserves. The freed-up oil can be exported for more revenues.

(4) Due to the accumulated oil revenues, Kuwait has a very strong fiscal position with high savings rate. The abundance of financial capital and government savings should be utilized to explore initiatives for RES. Moreover, RES will have a positive spill over the economy, including the creation of white collar jobs for the Kuwaiti labor force.

(5) Since the residential sector accounts for the bulk of electricity demand, the government must take major steps to reform the electricity and water subsidy program. This action will force the users to consume energy rationally, leading to a lower per capita energy consumption in the long run. It will also prepare users to accept and adapt to the introduction and implementation of RES.

(6) As Kuwait seeks to significantly increase its use of natural gas in electricity generation and water desalination, availability of natural gas (produced or imported) will determine the extent to which Kuwait can rely on CCGT to produce electricity. Within this context, the use of renewable energy as an alternative to reduce dependency on gas turbine options must be analyzed in formulating future energy requirements and supply.

## References

[1] International Energy Agency, "Kuwait country profile," 2010, http://www.iea.org/statist/index/.

[2] M. Ramadhan and A. Naseeb, "The cost benefit analysis of implementing photovoltaic solar system in the state of Kuwait," *Renewable Energy*, vol. 36, no. 4, pp. 1272–1276, 2011.

[3] N. A. Burney, M. Al-Enez, S. Hamada, and W. Awadh, "Peak-load electricity demand in Kuwait," *Economia International*, vol. 60, no. 3, pp. 273–290, 2007.

[4] M. Ramadhan and A. Hussain, "Kuwait energy profile for electrical power generation," *Journal of Strategic Planning for Energy and the Environment*, vol. 32, no. 1, pp. 18–25, 2012.

[5] M. N. Eltony, "The sectoral demand for electricity in Kuwait," *OPEC Review*, vol. 19, no. 1, pp. 37–44, 1995.

[6] N. AL-Mlutairi and N. Burney, "Demand for electricity in Kuwait," *Journal of King Saud University*, vol. 7, no. 1, pp. 3–17, 1995.

[7] http://www.kpc.com.

[8] International Energy Agency, "The project costs of generating electricity—2010 edition," Nuclear Energy Agency, OECD, 2010.

[9] *Ministry of Electricity and Water Statistical Yearbook*, Ministry of Electricity & Water (MEW), Kuwait City, Kuwait, 2010.

[10] G. P. Smestad, "The basic economics of photovoltaics for vacuum coaters," in *Proceedings of the 52nd Annual Technical Conference*, Santa Clara, Calif, USA, May 2009.

[11] A. H. Marafia, "Feasibility study of photovoltaic technology in Qatar," *Renewable Energy*, vol. 24, no. 3-4, pp. 565–567, 2001.

[12] S. Kumar and G. N. Tiwari, "Life cycle cost analysis of single slope hybrid (PV/T) active solar still," *Applied Energy*, vol. 86, no. 10, pp. 1995–2004, 2009.

[13] *Electrical Energy in Kuwait*, Ministry of Electricity & Water (MEW), Kuwait City, Kuwait, 2009.

[14] Enermodal Engineering Limited, *Cost Reduction Study for Solar Thermal Power Plants*, The World Bank, 1999.

[15] German Aerospace Center and Institute of Technical Thermodynamics, "Concentrating solar power for the Mediterranean region," Federal Ministry for the Environment, Bonn, Germany, 2005, http://www.dlr.de/tt/en/Portaldata/41/Resources/dokumente/institut/system/publications/MED-CSP_complete_study-small.pdf.

[16] http://www.solarbuzz.com/ModulePrices.htm.

[17] "GCC demand for gas growing faster than for oil," 2008, http://www.ameinfo.com/165303.html.

[18] World Energy Outlook, International Energy Agency (IEA), 2005.

[19] A. Y. Al-Hasan, A. A. Ghoneim, and A. H. Abdullah, "Optimizing electrical load pattern in Kuwait using grid connected photovoltaic systems," *Energy Conversion and Management*, vol. 45, no. 4, pp. 483–494, 2004.

[20] H. Doukas, K. D. Patlitzianas, A. G. Kagiannas, and J. Psarras, "Renewable energy sources and rationale use of energy development in the countries of GCC: myth or reality?" *Renewable Energy*, vol. 31, no. 6, pp. 755–770, 2006.