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The cost benefit analysis of implementing photovoltaic solar system in the state of Kuwait

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ABSTRACT

In addition to the high financial cost of energy resources required to meet the rising demand for electricity consumption in Kuwait, the negative environmental impact of fossil fuel is increasing. Hence, the objective of this paper is to determine the economic feasibility and viability of implementing PV solar energy in the State of Kuwait. It was found that the positive characteristics of solar radiation in Kuwait play a critical role in enhancing the feasibility of implementing solar systems. Under the present price of 5$/W and 15% efficiency, the LCOE of a 1 MW station is estimated to be around $0.20/kWh. This LCOE can be feasible only when the cost of oil is around 100$/barrel. The Cost Benefit Analysis showed that when the value of saved energy resources used in producing traditional electricity, and the cost of lowering CO_2 emissions are accounted for, the true economic cost of LCOE of a PV system will decline significantly. The preliminary economic analysis recommends the implementation of PV technology in Kuwait.

1. Introduction

Kuwait is a small open economy that is rich in hydrocarbon resources with proven crude oil reserves estimated to be around 104 billion barrels (9% of the total world oil reserves)[1]. While Kuwait is a major oil exporter, it also consumes a huge amount of its natural hydrocarbon resources to meet the rising demand for energy, in particular in the electrical power. Kuwait's total primary energy consumption reached around 195 million barrels oil equivalent in 2008 [1]. The energy requirements are met using available hydrocarbon resources, such as crude oil, natural gas, and fuel oil. However, most of the energy requirements are for electrical power generation. Assuming crude oil price per barrel at US$ 50, the total cost of primary energy sources is estimated to be nearly US $ 9 billions (around 10% of GDP in 2008). In addition to the huge value of the consumed and depleted resources, the large amount of fossil fuels consumed is negatively impacting Kuwait's local environment, through the emission of carbon dioxide, NO_x and SO_x gases. Kuwait's global image is also impacted since the country is rated as the third highest CO_2 emitter per capita in the world.

Over the last five decades, total consumption of electricity in Kuwait has increased drastically. Between 1960 and 2008, total consumption of electricity increased from 380 to 45,234 million kWh. The rise in consumption was largely due to increases in both per capita consumption and population. In 2008, annual per capita consumption of electricity was 13,142 kWh, and since 2000, it has increased at a rate of 6.8% per annum. During the same period, Kuwait's population increased at an average growth rate of 3.9% per annum. The growth rate in per capita consumption has surpassed the population and GDP growth rates. Several factors have influenced the accelerated rise in electricity consumption; the most important of these factors is the government electricity and water subsidy program. Since 1966, the government has subsidized more than 95% of the cost of electricity. Citizens and residents pay only 2 Fills/kWh (less than $0.01 or 1 Cent) out of the actual cost of producing electricity 34 Fills/kWh ($0.12/kWh). This public policy which aimed at increasing the public social welfare is characterized with a lack of energy conservation efforts and resulted in immense waste of natural resources in terms of allocation and efficient utilization. Moreover, the ineffective collection of electricity bills, where only 55% is collected in the past few years, enforced the irresponsible consumption of electricity by the public [2].

A number of studies have examined the factors affecting the demand for electricity in Kuwait [3–6]. In general, these studies have taken per capita annual electricity consumption as the

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[1] The GDP in 2008 was around $100 billion, and per capita income was estimated to be $39,914, one of the highest in the world. The economy depends heavily on oil exports and revenues, and on global economy both for commodity and factors (labor and capital). Kuwait has a very high saving rate (averaging 30% of GDP); by which huge financial surpluses were accumulated over the years and invested in global markets.

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dependent variable, and to introduce variation in the nominal electricity price, real electricity price has been used as the independent variable. The main findings of these studies are that electricity demand is inelastic with respect to changes in income or real electricity price. A reform of the electricity and water subsidy program has been emphasized by all studies. However, no studies have examined the economic suitability of Renewable Energy Sources (RES) for generating electricity in Kuwait. In particular, the economic cost and benefit of producing electricity with solar energy has not been addressed appropriately. Due to the abundance of hydrocarbon resources in Kuwait, the implementation of RES has always been viewed negatively by policy makers. Nonetheless, this view is changing as demand for green energy and the costs of fossil energy are increasing. This paper intends to examine the cost benefit analysis of implementing solar energy in Kuwait to meet part of the growing demand for electricity.

Among RES, solar energy is possibly the most suitable for the climatic conditions in Kuwait. Kuwait's annual solar irradiation is estimated at around 2100–2200 kWh/m^2. The average daily irradiation (direct normal) is also very high compared with countries that are currently among the main users of solar energy such as Germany and Spain. More significantly, Kuwait is rated as excellent in terms of its potential appropriateness for solar thermal power plants due to the high average daily irradiation and average high ambient temperatures [7]. Recognizing both the environmental and climatic hazards to be faced in the coming decades and the continued depletion of the world's most valuable fossil energy resources, Photovoltaic (PV) and Concentrate Solar Power (CSP) can provide critical solutions to electricity supply in Kuwait within relatively short time frame. Therefore, it is the objective of this paper to verify the economic feasibility of implementing PV solar power in the State of Kuwait, and to examine the economic benefit of solar energy. The rest of the paper will be structured according to the following: Section 2 presents the status of the Photovoltaic solar modules market and analyze the trends in its cost and efficiency. Section 3 examines the economic feasibility of implementing PV solar power in the State of Kuwait by determining the levelized cost of electricity (LCOE). Section 4 presents the cost benefit analysis of implementing PV solar system in the State of Kuwait. Section 5 evaluates the economic viability of solar energy. Finally, section 6 presents the main conclusions and recommendations.

2. Market analysis of PV modules

In 2009, the photovoltaic (PV) system installations reached the highest level of 6.43 Giga Watt (GW), a growth of around 6% over the previous year. The PV industry managed to generate $38 billion in global revenues in 2009. European countries accounted for 4.75 GW, or 74% of world demand in 2009. The top three countries in Europe were Germany, Italy and Czech Republic, accounting collectively for 4.07 GW. All three countries experienced high demand, particularly Italy which has become the second largest market in the world. The third largest market in the world was the United States, which grew 36% to 485 MW. World solar cell production reached 9.34 GW in 2009, up from 6.85 GW a year earlier. China and Taiwan production have increased rapidly (49% of global cell production) [8].

The two most important factors that affect the demand for PV systems are the module cost and cells efficiency. The major components of the PV system cost are the price of the PV module and the cost of the balance of system. Recent data indicate that PV module retail price index has declined significantly over the period (2001–2010) [8]. Specifically, the price/Watt peak in Europe has declined from €5.5 in 2001 to €4.1 in 2010. The same declining trend can be observed in United States. The recent module prices play an important role in lowering the cost of electricity generated by the PV system and, hence influencing the feasibility of solar PV applications. The efficiency of the PV module in generating electricity is another important factor influencing its feasibility. In this regard, the technological and scientific development over the last decade has improved the PV modules efficiency considerably. The recent data indicate that PV system efficiency has been increasing since 2004, and the increasing trend is expected to continue well into the future. Specifically, PV system efficiency is expected to increase from 15% in 2010 to 22% in 2020 [8].

3. The basics of photovoltaic economic

The application of PV economics goes as far as the industry itself. In the field of thin film PV, the work of Zwiebel [9,10] is among those that are widely referred to. Zwiebel methodology is easy to follow as it relates the cost of per square meter of the module to its cost per peak Watt and the cost of electricity in the installed PV system. Several recent studies have updated the field of PV economics for both organic and silicon-based technologies [11]. The cost of photovoltaic materials is expressed based on per unit area ($/m^2), but the modules are often sold based on cost per watt ($/Wp) that is potentially generated under peak solar illumination conditions. To convert the cost per square meter to the cost per peak watt ($/Wp), the Price$/Wp is estimated according to the following equation:

$$\$/\mathrm{Wp} = \frac{\$/\mathrm{m}^2}{n \times 1000\ \ \mathrm{Wp/m}^2} \tag{1}$$

For example, a PV module with 15% efficiency (n) and a cost 600 $/m^2 yields a price of 4 $/peak Watt.

3.1. The levelized cost of electricity of 1 MW PV station in Kuwait

The essential economic concept for any PV installation is that its cost should be recovered by the useful energy it produces over its lifetime. The levelized cost of electricity (LCOE) can be estimated from the ratio of the total life cycle cost to the total lifetime energy production according to the following reduced equation [12]:

$$\mathrm{LCOE} = \frac{(\text{Annual Cost} + \mathrm{OM})}{\text{Annual Output of the Station}} \tag{2}$$

$$\mathrm{CRF} = \frac{i \times (1+i)^n}{[(1+i)^n - 1]} \tag{3}$$

CRF represents Capital recovery Factor or the amortization of capital cost. This model has been used extensively in the analysis of economic feasibility of PV systems [13,14]. The following example will illustrate the estimation of LCOE for 1 MW PV station:

Station Annual output = Average Annual Insolation × Model Efficiency × Station Capacity

Installation Cost = Capital Cost × Station Capacity
Annual Cost = (Installation Cost × CRF) + O&M
LCOE = Annual Cost/Annual Output of the Station

The parameters for estimating the LCOE are given below:
Average Insolation/m^2/year = 2033 kWh
Efficiency = 10%
Project life = 20 years.
O&M = $7500 (3% of installation Cost per year)
Capital Cost = 500$/m^2 or (5$/W)
Interest Rate = 5%
Station Capacity = 10,000 m^2