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Trade-off between environmental and economic implications of PV systems integrated into the UAE residential sector

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ABSTRACT

PV technology offers clean resource and environmental advantages over fossil-fuel-based electricity generation; however, it remains more expensive than conventional technology in most grid-connected applications. The trade-off between environmental and economic parameters represents a challenge for governments. The objectives of this study are: firstly, to review studies in relation to the use of PV systems in the Gulf region and secondly, to assess the trade-off between environmental and economic parameters that influence the value of building integrated photovoltaic (BiPV) technology applied into the UAE building sector. This work examines residential buildings and concludes that the economic viability of BiPV systems is subject to capital cost, system efficiency and electricity tariff. To be a cost-effective option in the UAE, subsidies for PV investments and reasonable electricity tariff must be implemented. It is suggested that BiPV systems offer cost reductions in both energy and economic terms over centralised PV plants, especially if the costs of saved operating energy and avoided building materials are taken into account. Each square meter of BiPV is capable of making a significant reduction in CO_2 emissions generated by conventional power plants. This will limit the impact of global warming on the UAE and others.

Contents

1. Introduction

The United Arab Emirates (UAE) is characterised by favourable geographical conditions and represents a major oil producing country. During the past few decades, the UAE has witnessed an unprecedented economic and social transformation. Oil proceeds have been used to modernise infrastructure, create employment and improve social indicators. Due to this expenditure, the UAE has become a major CO_2 emitter [1]. In one decade (1997–2006), the primary energy increased by almost 60% with a 15.3% increase between 2007 and 2008 [2]. While at the same time, the increase in CO_2 emissions due to energy use reached between 33% and 35%

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[3]. Today, the use of solar technologies is representing one of the most promising, reliable and environmentally friendly renewable energy technologies, which has the potential to contribute significantly to the energy and environmental system in the UAE region. A technical field study carried out by the Centre Suisse d'Electronique et Microtechnique (CSEM)-UAE Innovation Centre [4] found a linear increase in photo-generated current due to increase in solar radiation. However, it was observed that the PV module efficiency dropped by 3–4%, compared with standard test conditions (STC), due to the high range of PV module temperatures (50–60 °C) and the power output changed due to high ambient temperature on the site. Another study [5] showed that if BiPV was applied into commercial buildings, a considerable amount of electricity could be saved. Consequently a large amount of CO_2 emissions could be reduced. The current research assesses the value of BiPV systems in the UAE residential sector and highlights parameters influence such value.

Many studies and experiments in the Gulf region have suggested different assumptions and presented numerous results. Studies in energy policy [6–9], on the one hand, are very optimistic about the use of renewable energy stating that renewable energy sources are expected to play a greater role in the future based on the rich natural potential of the region [10]. Moreover, the use and development of renewable energy technologies can make a significant contribution to improving environmental protection and to guaranteeing continuing oil supplies in conditions of stability and security in the Gulf region [11].

On the other hand, experimental and technical studies in renewable energy are more conservative. Recent studies in Saudi Arabia claimed that despite the abundant availability of solar energy PV systems alone could not satisfy building loads on a 24-h basis. Nevertheless, hybrid systems with different combinations of wind and photovoltaic (PV) panels were able to provide a great portion of the energy demand [12]. In general, PV technology could not be considered as a cost-effective technology with the current energy price and PV system cost [13]. As for Bahrain, the adoption of solar technology was said to be very advantageous, albeit with a number of drawbacks, while the use of wind energy was not encouraging [14]. At the same time, the grid connected PV systems in Kuwait could be a promising technique to enhance the performance of traditional grid utility systems. Such systems were expected to be economically feasible [15]. In an attempt to optimise the electrical load pattern using grid connected PV systems, the peak load was found to matched the maximum irradiance level in Kuwait, which would emphasise the role of using PV stations to minimise the electrical load demand coupled with achieving a significant reduction in peak load [16]. However, if PV stations were proposed to be installed, the capital cost per PV installed peak watt must be less than the 90th prices [17]. In order to emphasise this result, a sensitivity analysis was performed to the capital cost per installed PV peak watt, discount rate, and operating peak hours [18]. The present Qatari PV stations, however, were indicated as not economically feasible compared with conventional gas turbine stations [19]. In Oman, the PV technology was examined and its effectiveness proven, to a certain extent. It held great promise for electricity generation but, at the current time, was a relatively high capital-cost process [20].

Clearly, the majority of studies in the Gulf region focused on large scale applications and dealt mainly with technical and economic aspects. The value of PV technology, however, needs to be evaluated in the light of environmental and even social parameters [21]. Technical, economic and environmental parameters play a significant role in the assessment of PV value. Such parameters were considered in the evaluation of PV technology as electricity sources for many countries with different conditions [22]. The cost effectiveness of PV technology and its impact on the environment, for example, was demonstrated in Jordan [23]. The same situation can be seen in Brazil where the BiPV technology was presented as an interesting potential for decentralised generation in urban areas [24]. However, this was not the situation in Serbia, where the integration of PV into the envelope of urban buildings was found to be not economically viable [25]. The same situation was repeated in Montreal. Due to the high cost of the solar technologies and the low cost of electricity, financial payback of BiPV was never achieved [26]. While at the same time, techno-economic assessment of a BiPV system in Greece concluded that the high initial cost of the BiPV system was a prohibitive factor for the implementation of PV projects and there was no incentive for central grid-connected consumers to purchase a PV system for their electricity supply [27]. However, technical optimisation of PV panels might influence the economic viability [28]. If environmental benefits were considered then the specific investment would soon be worth considering [29]. From this perspective, the integration of PV panels into buildings in China helped in producing electricity and cutting down electric lighting and cooling energy requirements to benefit the environmental, energy and economic aspects [30].

Based on the above, the consideration of technical and non-technical factors plays a significant role in the accuracy of PV value. Ignoring any of these factors may make solar PV to be seen as the greatest or worst opportunity of electricity generation. According to a recent study in the UK [31], the trade-off between environmental and economic implications enables PV technologies to be cost effective. This trade-off can be reduced when the benefits of BiPV are considered. The study suggested that BiPV systems offer double benefit of reduced economic costs and improved environmental performance when compared with centralised PV plants. Another study in the UK [32] indicated that PV technology was not viable in comparison with conventional electricity sources. However, it was viable in the sense that it provided significant environmental benefits over conventional electricity sources on the grounds that adoption of such a technology would have social benefits outside the sphere of monetary evaluation.

The present work evaluates the impact of environmental benefits and economic parameters on the value of BiPV technology for the UAE residential sector. It assesses the BiPV from an environmental and economic point of view and identifies environmental and social parameters that stimulate decisions of UAE policy regarding the PV technology.

2. Methodology

A three step procedure was followed in assessing the BiPV value including technical study, economic assessment and environmental analysis.

2.1. Technical study

Abu Dhabi and Sharjah were chosen to represent different emirates in the UAE. Each has its own economic and social situation. As depicted in Table 1, a prototype residential building was developed and a building integrated photovoltaic (BiPV) system then designed. The PV system was assumed to be integrated into the skin of the prototype house. The PV panels were first applied into the roof with a 15 cm air gap and then into the southern wall with a tilt angle of 24°. Sanyo single crystalline silicon solar cells were used and assumed to have an efficiency of 15.2%. The specification of the PV system are given in Table 2. The Energy-10 simulation software [33] was used to model the BiPV performance and its impact on building energy behaviour under the real weather conditions of the studied emirates.