The Economic Viability of Solar Photovoltaics within the Saudi Residential Sector

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Abstract

Renewable energy options, including solar power, are becoming progressively more viable and thus increasingly pose challenges to conventional sources of energy, such as oil, coal and natural gas. Solar Photovoltaic technology is one type of solar energy technologies that has recently received substantial attention because it offers the possibility of providing clean power sources for buildings. The aim of this paper is to examine the economic viability of using photovoltaics within future residential buildings in the oil-rich Saudi Arabia. The study reveals that significant benefits, economic and other wise, could be realised as a result of such an endeavour.

1. Introduction

Electricity consumption has increased sharply in Saudi Arabia over the last two decades, mainly due to a rapid economic development and an absence of energy conservation measures. Other contributing factors include a rapidly growing population (with a current annual population growth rate of about 3%) as well as artificially low electricity prices (due to low government-mandated tariffs and heavy consumer subsidies as part of a social welfare programme). Several studies have therefore shown a sharp increase in electricity consumption in Saudi Arabia, with an average demand growth of 7% per annum (Al-Ajlan et al., 2006; Al-Saleh, 2007; Saudi Ministry of Water and Electricity, 2008). In order to curb this increasing demand, the Saudi Government should soon start to consider a slow and gradual lifting of consumer subsidies as well as the launching of several campaigns in order to promote energy efficiency. It is hoped that the Government would also consider providing financial incentives in order to promote the decentralised (i.e. micro) generation of clean electricity (National Energy Efficiency Plan, 2008).

Given the abundant availability of solar radiation in Saudi Arabia, solar photovoltaics (PV) appears to be an attractive and environmentally-friendly energy option (Taleb and Pitts, 2008). The aim of this paper is to quantitatively examine the prospects of decentralised PV-based electricity generation in new houses in Saudi Arabia. Firstly, the current and future demand (over the period 2010-2025) for housing and the associated electricity use in the country is discussed. After that, the economic viability of having PV providing 10% of the electricity to be used in new homes is examined in detail.

2. Electricity Consumption within the Saudi Residential Sector

It should be mentioned here that, for the purpose of this study, the focus is placed upon villas and apartments which are the conventional forms of residence in Saudi Arabia. Other types of dwellings such as tents, still exist in the country, but in very small numbers; hence were excluded from this particular study. According to forecasts provided by the Saudi Ministry of Economy and Planning (2005), approximately 2.2 million new villas and apartments will be required over the period 2010-2025. The following chart demonstrates the annual breakdown of such a high level of demand over this relatively short period of time.

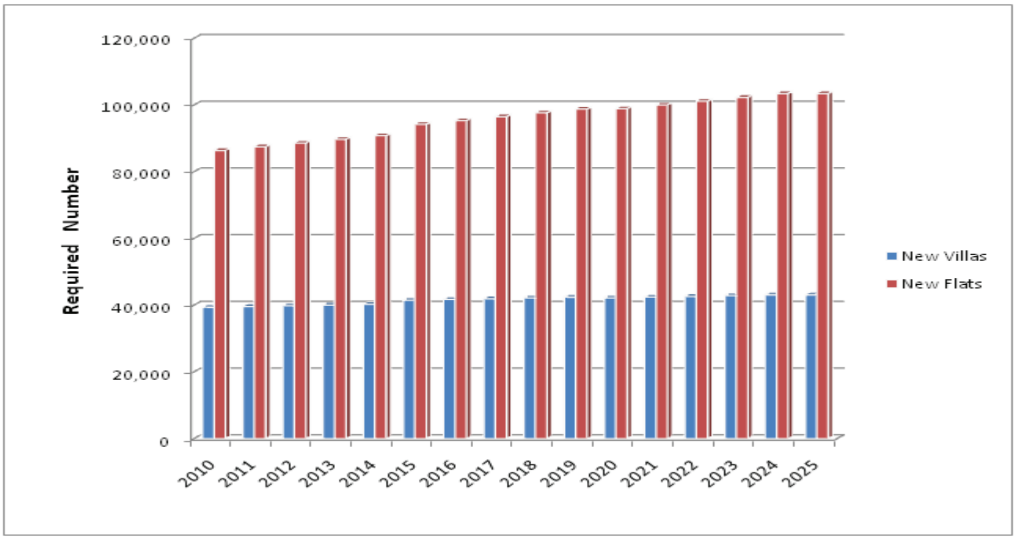

Figure 1: Anticipated Demand for New Houses in Saudi Arabia over the Period 2010-2025

At present, residential electricity consumption (where subsidies are the highest) is almost the same as the sum of all the other sectors in the country (see Figure 2). Moreover, in a time of global concern over energy and environmental issues, ignorance of efficient building design and the absence of 'time-of-use' electricity rates leads to approximately 80% of electricity being used for air conditioning and refrigeration (Alnaser and Flanagan, 2007; Iqbal and Al-Homoud, 2007). Consequently, electricity shortages are acute during the summer season, when demand is at its peak.

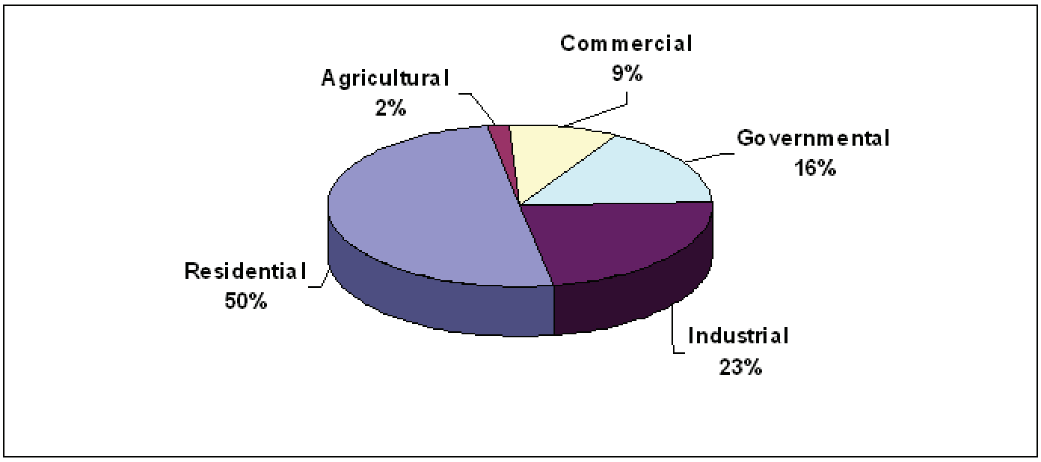

Figure 2: Electricity Consumption Breakdown Percentage by Sector in Saudi Arabia
(Source: Al-Ajlan et al., 2006)

The Saudi Ministry of Water and Electricity (2008) however argues that a potential reduction of 40% is possible in Saudi household electricity consumption through the application of energy saving and conservation measures. Therefore, based on data provided by Al-Ajlan et al. (1997, 1998) and Al-Mofeez (2007),

Table 1 illustrates the annual electricity consumption for a typical apartment and a detached three-bedroom villa in Saudi Arabia. Bearing in mind that electricity consumption in Saudi Arabia is much more significant during the hot summer months, the table below shows typical consumption figures that have been averaged throughout the year.

Table 1: Typical Annual Household Electricity Consumption in Saudi Arabia (in kWh/year)

	Villa	Apartment
Without Efficiency Improvement	43,000	20,000
With Efficiency Improvements	25,800	12,000

Assuming that the above figures remain constant over the period 2010-2025, it is possible to estimate the total electricity needs of new Saudi houses per annum. This could be carried out for two scenarios (namely 'with' and 'without') in order to reflect either the application or absence of energy efficiency means within the Saudi residential sector. Thus, by multiplying the consumption figures provided in Table 1 by the anticipated number of new houses shown in Figure 1, the following figure illustrates the amount of electricity to be consumed annually by new houses built over the period 2010-2025, for both the cases of 'without' and 'with' respectively.

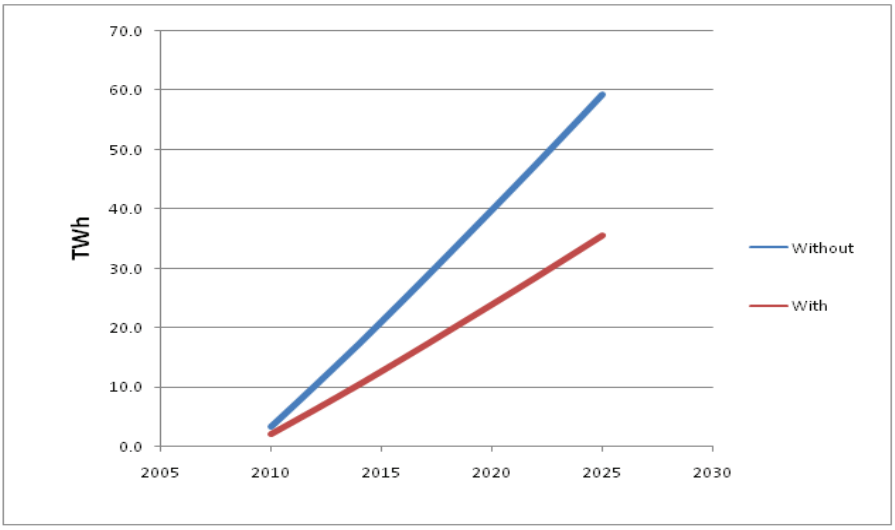

Figure 3: Anticipated Annual Electricity Consumption in New Saudi Houses through to 2025

Having estimated the total electricity consumption of new Saudi houses per annum over the period 2010-2025, the next section examines the economic viability of installing PV panels to meet some of this increased demand.

3. Economic Feasibility of Using PV to Power New Saudi Houses

It should be acknowledged here that the assumptions adopted in the following calculations, unless stated otherwise, were borrowed from a recent study by Al-Saleh et al. (2008). This was a major Delphi study, in which thirty five experts participated, with the aim of developing a suite of renewable energy scenarios for Saudi Arabia through to the year 2050.

For starters, it is necessary to estimate the required installed power capacity that would provide the anticipated amount of electricity to be consumed in Saudi houses in the future. After assuming a difference of 20% between Saudi production and consumption in order to account for all potential production and distribution losses between power plants and houses, the average power demand per annum (in GW) was obtained by multiplying the values in Figure 3 by 1,000 (to convert Terawatts to Gigawatts) and then dividing by 8,760 hours (i.e. 365 days x 24 hours). Assuming a typical load factor of 65%, the anticipated peak demand per annum would be the estimated annual average power needs divided by the assumed load factor (Ellicott et al., 1998). Finally, the required installed capacity per annum (illustrated in Figure 4) is calculated by adding the anticipated annual peak demand and adding a reserve margin of 15% (Rotmans and Vries, 1997). In essence, these annual additions (measured in installed GW) will be required in order to power only the new houses in Saudi Arabia that are to be built over the period 2010-2025. They do not take into account the requirements to power existing houses (an aspect which is not within the scope of this study).

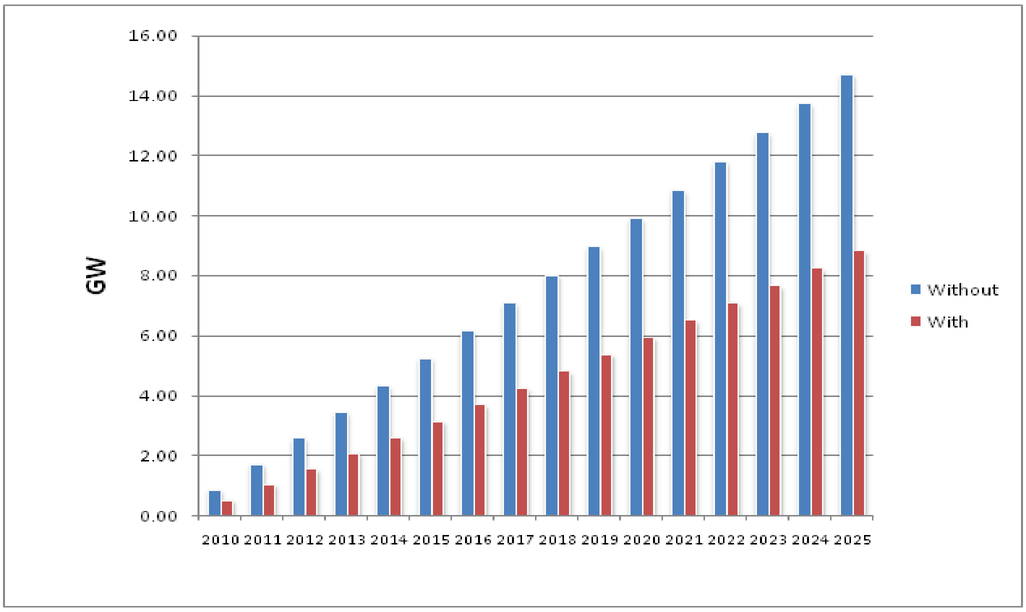

Figure 4: Anticipated Installed Capacity Required to Power New Saudi Houses through to 2025

The vast majority of Saudi electric power is currently being generated using open-cycle gas turbines or steam boilers. Given that the - presently significant - share of natural gas for electricity production is set to increase in Saudi Arabia (IEA, 2005), it has been decided to compare the prospects of PV with what currently prevails (i.e. simple-cycle gas turbines that use natural gas as a fuel). It might, however, be worth remembering that the PV technology is characterised by high capital cost and zero fuel costs, unlike conventional technologies in which fuel costs are high and initial investment is much lower than in the case of renewables. Hence, a lifecycle approach is required to examine the economics of energy technologies. Based on the outcomes of the aforementioned Delphi study (i.e. Al-Saleh et al., 2008), the price of natural gas is assumed to increase from 0.21 to 0.3 USD/m^3 whilst the figure below provides a forecast for PV and gas turbine technologies' capital costs over the period 2010-2025.

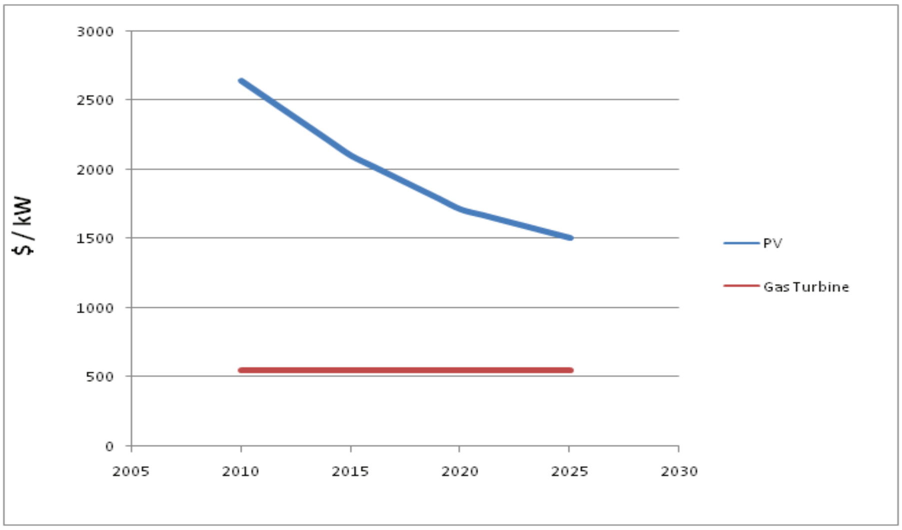

Figure 5: Capital Cost Forecast for the Power Technologies under Consideration through to 2025

In order to examine the economic prospects of having PV panels (as opposed to fossil-fuel based power generation) provide 10% of the electricity consumed by future new Saudi houses, *RETScreen International Clean Energy Project Analysis Software* seemed to be an attractive and powerful tool to use. RETScreen Software provides an evaluation of lifecycle costs, financial viability and risk analysis for various types of energy technologies in order to determine whether or not the balance of costs and savings (i.e. cash flow) over the lifetime of an energy technology makes for a financially attractive proposition.[1] Whilst RETScreen Software does not account for 'external costs' to society and the environment owing to the burning of fossil-fuels, it calculates any greenhouse emission reductions that might result from the use of clean-energy technologies.

[1] The detailed calculations and various mathematical equations used by the RETScreen Software are documented at: http://www.retscreen.net/ang/t_training.php

This software is provided by Natural Resources Canada (NRCan) and has been developed with the contribution of several experts from government, industry and academia. Integrated within this software are databases for product, cost and climatic conditions (i.e. meteorological data sets from both ground and NASA satellite databases).

The following table lists the assumed parameters and RETScreen model input data that were adopted in order to carry out this economic feasibility study.

Table 2: RETScreen Model Input Data

Make of solar PV	BP Solar
Make/model of gas turbine	GE MS6001B (42.1 MW)
Power Technology Lifetime	25 years
Discount rate	8%
Inflation rate	2.5
Debt ratio	50%
Debt interest rate	7.7%
Debt term	15 years
Depreciation rate	30%
Depreciation tax basis	95%
Annual Operation & Maintenance (O&M) cost for solar PV	1% of PV capital cost
Annual O&M cost for natural gas-fuelled gas turbines	25 USD/kW
Annual greenhouse gas (GHG) reduction credit rate	5 USD/tCO^2
GHG credit annual escalation rate	2%
Annual GHG credit transaction fee (fixed)	2%
Financial 'incentives and grants' for using PV	20% of capital cost
To account for a gradual lifting of current subsidisation of fossil fuel-based power generation	0.5% annual increase in 'incentives and grants'
'cost of saved energy' when applying energy saving measures	$20/MWh
Capacity factor - or availability - for solar PV (2010-2025)	30% - 34%
Capacity factor - or availability - for gas turbine (2010-2025)	80% - 82%

Having built and run the RETScreen software using the above assumed parameters, a bright prospect for using PV within new houses in Saudi Arabia is apparent. For instance, the calculated 'payback period' is about 11.8 years at 2010; and it gradually drops down - mainly due to falling PV capital costs - to only 3.7 years by 2025. The payback period essentially refers to the length of time that it takes for a project to recoup its initial investment, out of the income and savings it generates. Therefore, the more quickly the cost of an investment can be recovered, the more desirable and viable it is. Bearing in mind that the 'payback period' should only be seen as a simple - not a principal - indicator for evaluating the attractiveness of a project, an attempt was made to further investigate the economic viability of installing PV within new Saudi houses. More specifically, an attempt was made to calculate the potential lifecycle 'savings' per annum over the period 2010-2025. In essence, this annual lifecycle 'savings' =

Fuel cost savings (i.e. cost of natural gas for an equivalent gas turbine-based power generation)

+ O&M savings that resulted from using the PV technology

+ Any revenue resulting from GHG reductions

+ Any financial incentives to promote renewables

– Levelised debt payments to pay off the capital cost (i.e. difference between capital cost of PV and that of gas turbine-based power generation)

– Cost of saved energy (in scenarios 'with' energy saving measures applied)

The figure below illustrates the calculated potential annual lifecycle savings. These are essentially relative to a baseline/reference scenario that does not utilise the PV technology.

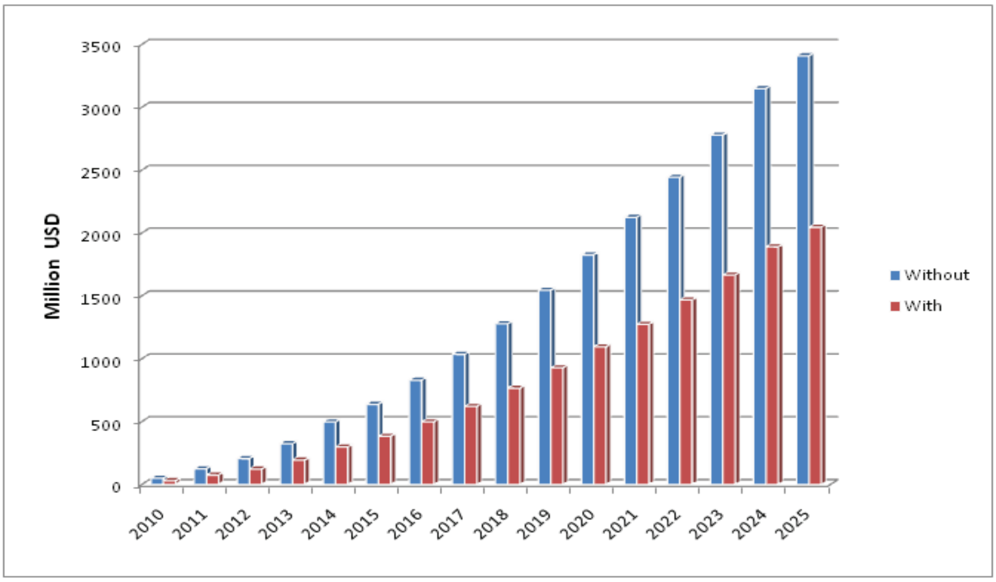

Figure 6: Estimated Annual Lifecycle Savings through to 2025

More annual savings are anticipated with regard to the 'without' scenario which refers to the absence of energy saving measures. This scenario assumes that more installed power is required, thus a larger deployment of PV, when compared with the 'with' scenario. Nonetheless, it should be borne in mind that such levelised lifecycle estimates are not intended to provide a definite guide to actual electricity-generation investment decisions. Instead, their role should be limited to providing a 'first order assessment' as they are based on long-term forecasts which could well be subject to a substantial degree of error. Besides the anticipated monetary savings, it was decided that a useful indicator would be investigating the environmental implications of using the PV technology within the Saudi residential sector. Therefore, the RETScreen model was used in order to estimate the potential magnitude of greenhouse gas (GHG) emissions that could be reduced over the time horizon of 2025.

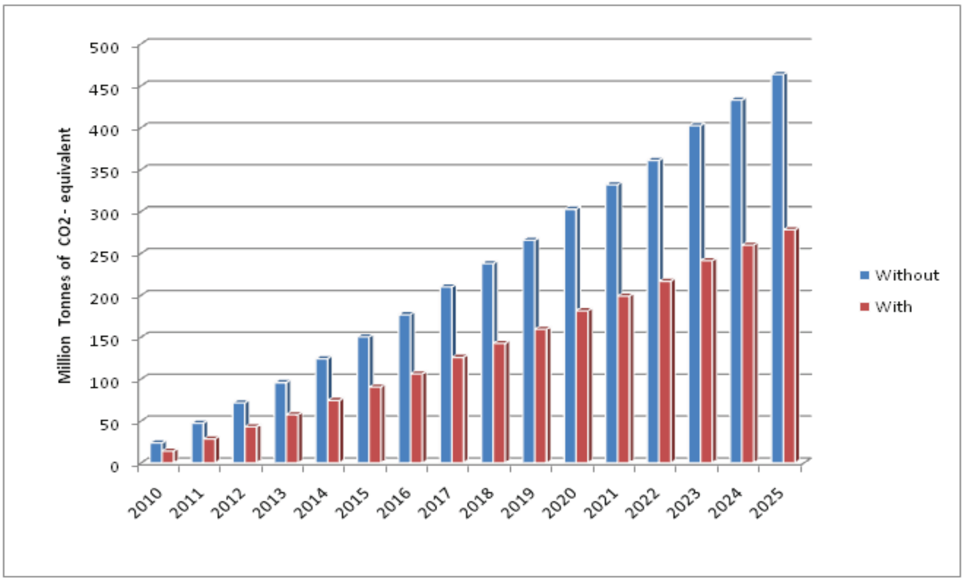

Figure 7: Estimated Annual Greenhouse Gas Reductions through to 2025

The total GHG emission reductions are anticipated to be 3.7 and 2.2 billion tonnes of CO_2 - equivalent, for the cases of 'without' and 'with' respectively. In addition, an effort was made to work out the potential savings of fossil fuels that would have otherwise been used for conventional electricity-generation over the period 2010-2025. Expressed in terms of barrels of crude oil, it was calculated to be around 7.7 and 4.6 billion barrels of crude oil for the scenarios of 'without' and 'with' respectively. Indeed, such potentially huge savings of a rapidly diminishing natural resource could help in either freeing additional oil for export or - perhaps more importantly - stretching the lifetime of the country's most precious export good.

4. Conclusion

With regard to recent energy and environmental concerns, there is an apparent global enthusiasm for renewable energy options. Saudi Arabia, despite being a major oil producer and exporter should not be seen as an exception in this regard. It is believed that 'now' is the appropriate time to invest in developing capabilities in the arena of renewable energy in order to secure the country's future for a sustainable economy and to address its rapidly-growing energy needs. This paper examined the economic viability of using a single renewable energy technology (i.e. solar PV) within Saudi houses (i.e. the single largest electricity consumer in the country). In effect, this feasibility study has adopted a timeframe of 2010-2025 in order to look into the prospects of using PV within Saudi houses in the future under two possible scenarios, i.e. either an introduction or a continued absence of energy efficiency means. Apparently, the outcomes of this study show that such an endeavour would not only bring about economic benefits to the country, but also to the world as a whole (particularly in terms of GHG reductions due to reducing the dependence on fossil fuels).

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الجدوى الاقتصادية لاستخدام الخلايا الشمسية في قطاع الإسكان في المملكة العربية السعودية

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الملخص:

تقدم تقنيات الطاقة المتجددة وسائل بديلة للحصول على طاقة مستدامة ونظيفة، من ضمن هذه التقنيات التي اثبتت فعاليتها نجد الخلايا الشمسية (الفولتضوئية) والتي انتشر استخدامها في العالم أجمع، لقد جذبت هذه التقنية إنتباه العالم مجدداً عندما اثبتت فعالية دمجها في المباني. تهدف هذه الورقة إلى دراسة الجدوى الإقتصادية لإستخدام تقنية الخلايا الشمسية في المباني السكينة المستقبلية في المملكة العربية السعودية. أفرزت هذه الدراسة المستقبلية عن نتائج مهمة واقترحت فوائد عديدة ممكنة لاستخدام الخلايا الشمسية، شملت الفوائد التي تطرقت لها هذه الدراسة: العوائد الإقتصادية والبيئية بالاضافة إلى تقليل الإعتماد على الوقود الأحفوري في المملكة.