TECHNO-ECONOMIC ANALYSIS OF A BUILDING APPLIED PV SYSTEM

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Overview

The building sector, accounting for over one third of global energy use and greenhouse gas (GHG) emissions, has to play an important role in the sustainable energy transition. Buildings in the developed countries are undergoing an enormous revolution in enhancing their energy efficiency and environmental performance. The use of sustainable energy has been an essential feature of these initiatives. Solar PV is one of the most popular renewable technologies in the building sector across the world. PV can significantly assist the building sector in improving its self-adequacy of energy and reducing environmental emissions cost-effectively. This paper aims to investigate the techno-economic performance of a 25 kWp rooftop PV system.

Methods

Performance analysis of the PV system, installed on the rooftop of a commercial building, has been carried out with the help of real-time data measured over three years. Technical performance of the PV system examines parameters like DC and AC power output, array yield, specific yield, references yield, array losses, and PV system efficiencies. It also calculates capacity factor and performance ratio. An economic analysis of the PV system has been undertaken with the help of parameters like levelized cost of electricity, simple payback period and discounted payback period. Environmental assessment of the PV system has been carried out in terms of the avoided greenhouse gas emissions. A sensitivity analysis has also been conducted to evaluate the impact of various techno-economic factors on the feasibility of the installed PV system and it is found that the PV system becomes more viable with a blend of clean energy-friendly policies and economic supports.

Results

This paper investigates the techno-economic and performance of a 25 kW PV system taking into account important technical, economic, and environmental parameters besides undertaking a sensitivity analysis. The annual DC and AC outputs of the system have been found to be 42.94 MWh and 41.86 MWh respectively. Monthly performance ratio and capacity factor are shown in Figure 1. The analyses are based on real-time data gathered through a robust PV performance monitoring system.

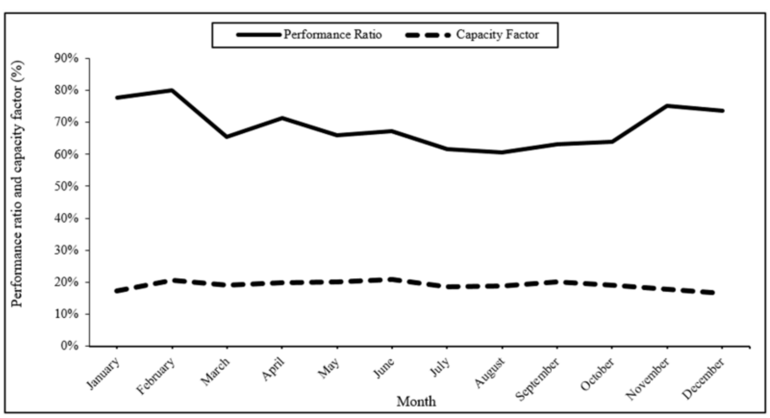

Figure 1: monthly performance ration and capacity factor of the PV system

The annual average values of performance ratio and capacity factor of the PV system have been calculated to be 68.09% and 19.05%. The environmental analysis reveals that the PV system can save 805.11 tons of CO_2, 24.86 kg of CH_4 and 4.28 kg of N_2O over the project life. The economic assessment reveals the life cycle cost for 25-years project life to be USD 48,524 with simple payback period and discounted payback period of 10.6 years and 11.5 years, respectively.

Conclusions

Solar PV systems are becoming an integral part of the sustainability drive in the building sector across the world. Solar PV is a relatively new technology in KSA's building sector, which can significantly help improve the energy and environmental footprint of buildings. This study examines the techno-economic performance of a 25kW PV system installed on a residential building in KSA. A simple payback period of 10.6 years is likely to be perceived as quite expensive by many residential consumers. The situation can be significantly helped through appropriate regulatory and financial support mechanisms and lessons can be learnt from the developed countries. The study, for example, concludes that direct financial incentives and carbon credits to be useful towards improving the economic viability of the PV system. In KSA, the viability of PV systems can significantly improve with the removal of subsidies on electricity tariff.

BUILDING ENERGY RETORFIT FOR SUSTAINABLE ENERGY TRANSITION

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Overview

Energy conservation and management is one of the most promising dimensions of the sustainable energy transition. Buildings, accounting for 36% of the world's total energy use and around 40% of the greenhouse gas (GHG) emissions, play an important role in the global energy and environmental scenario. A building consumes energy throughout its life cycle. The operational phase of a building is responsible for most of the energy consumption, accounting for up to 90% of the life cycle energy use. Compared to other sectors such as transport, industry, and agriculture, the building sector has the greatest potential for reducing energy consumption and GHG emissions. To improve the sustainability standards in the building sector it is imperative to retrofit the existing buildings which account for the bulk of the building stock. This work explores the prospects of retrofitting in residential buildings of the Kingdom of Saudi Arabia (KSA).

Methods

The retrofitting methodology consists of six steps: selection of case study buildings, selection of energy efficiency measures, development of building energy models, energy analysis, environmental analysis, and economic analysis. Prototypical models of two residential building types, villa and apartment building, are developed and used as cased studies. These two residential building types are selected because, collectively, they represent 70% of the existing building stock in KSA. The villa model is a single-family detached house of two floors, while the apartment building model is a multi-family building of three floors with two apartments per floor. The spatial arrangements and construction details of the two case studies are typical and represent the local architecture.

Results

The results of the energy and environmental assessment of retrofitting indicate significant savings can be realized in residential buildings. In case of the studies villa, a reduction in the annual energy consumption of 51%, 51%, 50%, 31%, and 47% is achievable in the climate condition of Jeddah, Riyadh, Dhahran, Guriat, and Khamis Mushait respectively, and for the apartment building a reduction of 64%, 64%, 65%, 60%, and 61% is achievable in each city respectively. Furthermore, the designed PV system can offset 43%, 43%, 42%, 42%, and 41% of the energy demand for the villa, and 41%, 41%, 41%, 42%, and 39% of the energy demand for the apartment building in the respective cities. The environmental assessment results indicate a reduction in the rate of CO_2 emissions by 72%, 72%, 71%, 60%, and 69% for the villa, and in the apartment building, it is reduced by 79%, 79%, 80%, 77%, and 77% in the respective cities.

Conclusions

An energy and environmentally efficiency building sector is an integral part of the sustainable energy transition. Energy and environmental footprint needs to be improved both for the new buildings as well as the existing building stock through retrofitting. In KSA, retrofitting is a relatively new concept for the building sector. The study has shown that the annual energy demand in the residential sector of KSA can be curtailed by a substantial amount of 20,167.91 GWh, and the CO_2 emissions by 13.82 Mt. In addition, the retrofitted homes can cumulatively supply 13,071 GWh of energy to the existing grid by the rooftop PV systems. It is proposed that a comprehensive plan to energy retrofitting residential buildings should be adopted to make the building sector more sustainable in order to help address the country's energy and environmental footprint. In the current scenario, the economic viability of retrofitting has question marks. There is need for conducive policy frameworks and meaningful financial incentives to boost retrofitting of buildings in KSA as has been the case in the developed countries.

THE FOUR DYNAMICS (4Ds) OF ENERGY TRANSITION: DECARBONIZATION, DECENTRALIZATION, DECREASING USE, AND DIGITALIZATION

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Overview

The human use of energy has evolved through the course of history. Availability of refined and efficient energy resources has played a decisive role in the advancement of societies, especially since the industrial revolution of the eighteenth century. In the twenty first century, the international energy scenario is experiencing a profound transition as the world is experiencing a major shift in terms of energy resources and their utilisation. In recorded history, there have been two major energy transitions. The first one was a shift from wood and biomass to coal during the 18^{th} century industrial revolution, and the second one was the 20th century transition from coal to oil and gas. The 21^{st} century energy transition is manifested as sustainable energy transition or zero-carbon energy transition. This work examines the major dimensions of the unfolding energy transition taking into account key policy drivers and trends, technologies, challenges, and prospects.

Methods

The work explores the international energy and environmental scenario to determine the important technological and policy dimensions of the ongoing energy transition. It examines the frameworks, directives and outlooks of relevant national and international bodies and policy institutions, utilities, industry, academia, research and development (R&D) organizations, and development sector. A survey has also been conducted to determine the perspective of key stakeholders - i.e. policy and decision making circles, utilities, industry, academia, research and development (R&D) institutes, financial institutes, developmental sector and civil society - on the dynamics of the energy transition.

Results

The main findings of the work are as below.

- The key drivers of the ongoing energy transition include: climate change, energy insecurity, rising energy prices, and depleting fossil fuel energy reserves.
- The technological dimensions of energy transition can be classified under four broader categories: decarbonisation, decreased use (energy efficiency), decentralisation/distributed generation, and digitalisation
- Major challenges to a successful energy transition include lack of conducive policies, technological and investment constraints, and geopolitical disputes
- The energy transition requires dynamic and interwoven technology-policy partnership
- Localized socio-economic inequalities around energy insecurity are also a global concern
- The planet, a global village, has a shared future, for the developed and the developing nations.

Conclusions

The 21st century energy transition is much more vibrant and multidimensional as compared to the 19th and 20th century energy transitions thanks to the enormous changes and advancements on the fronts of energy resources and their consumption, technological advancements, socio-economic and political response, and evolving policy-landscape. This energy transition is driven by the global pursuit for sustainable development having energy and environmental sustainability at its heart. In terms of technology, the present energy transition has four broader dimensions: decarbonisation, decreased use, decentralisation, and digitalisation. Decarbonisation of the energy sector is led by solutions like renewable and low-carbon technologies, electric mobility, carbon capture and storage, and hydrogen and fuel cells. Decreased use of energy through energy conservation and management (ECM) is critical to energy sustainability. ECM is a widely established and techno-economically viable strategy across all major energy consuming sectors. Distributed generation or decentralised energy systems are becoming popular around the world to help cost effective and efficient supplies of energy. Digitalisation of energy systems is also deemed to be an important aspect of future energy systems. The International Energy Agency (IEA), regards energy digitalisation as important to help improve productivity, accessibility, cost-effectiveness, and overall sustainability of future energy systems.

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