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INTEGRATING SOLAR PHOTOVOLTAIC SYSTEMS FOR ENERGY MANAGEMENT: A CASE STUDY OF A HIGHER EDUCATIONAL INSTITUTE

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ABSTRACT: This paper presents a study on integrating solar energy into a higher educational institute to meet Sustainable Development Goal 7.1, which focuses on universal access to affordable, reliable, and modern energy services. This study focuses on implementing solar photovoltaic (PV) systems at the Institute of Technology, University of Moratuwa (ITUM), Sri Lanka to address rising energy costs and reduce carbon emissions. ITUM, which accommodates approximately 1,600 resident students and 200 staff spent approximately 33 million LKR on energy in 2022. This research proposes the installation of 450 kWp solar PV system to cover 65% of the institute's daytime energy consumption, generating an estimated 57,956 kWh per month. The system is projected to provide monthly savings of 2.17 million LKR. With a total investment of 48.04 million LKR and an estimated payback period of 2 years, the solar installation will reduce ITUM's carbon footprint by 395 MT of carbon dioxide annually. The integration of solar energy at ITUM demonstrates a viable approach to achieving financial savings, improving energy sustainability, and fostering environmental responsibility within educational institutions.

Keywords: carbon footprint, energy management, higher educational institute, solar PV energy

1. INTRODUCTION

Energy management in higher education institutions is crucial to ensure not only the sustainability of educational programmes but also the maintenance of a minimum carbon footprint. Many organizations focus on strategies to reduce energy costs and carbon footprints with concern for increasing energy prices and the impacts of climate change. Target 7.1 of the United Nations' Sustainable Development Goals ensures universal access to affordable, reliable, modern energy services (Parra et al., 2020). The sustainability of educational programs relies on the availability of infrastructure and resources needed for the smooth operation of educational programs, research and development, and staff and student welfare. Energy costs can be reduced by various strategies such as energy conservation by efficient usage of equipment and instruments and switching to cost-effective renewable energy sources. Many strategies and practices are focused on reducing energy consumption in universities and higher educational institutes by using energy-efficient technologies and promoting sustainable practices among students and staff, such as encouraging the use of public transportation, rainwater harvesting, recycling, and reducing waste. For higher education institutes, energy management not only supports global sustainability efforts but also ensures the continuous delivery of academic programs and the well-being of future leaders (Purcell et al., 2019).

The Institute of Technology, University of Moratuwa (ITUM), is a prominent technical education provider in Sri Lanka, accommodating approximately 1,600 resident students and 200 staff members. ITUM has experienced a rapid increase in energy costs from 22 million LKR in 2020 to 33 million LKR in 2022. The COVID-19 pandemic temporarily reduced energy consumption due to limited on-campus activities. However, when the operations returned to normal, energy usage surged. These rising energy expenses, coupled with a significant increase in water costs, have placed a substantial financial burden on the Institution (ITUM, Annual Report 2020, n.d.; ITUM, Annual Report 2022, n.d).

Conducting energy audits can help identify areas where energy is wasted, enabling targeted improvements. Furthermore, integrating renewable energy sources, such as solar PV systems or wind turbines, can significantly reduce dependency on non-renewable energy. Energy saving in higher educational institutions is important for several reasons. Firstly, it reduces operational costs, allowing institutions to allocate more resources to educational programmes and student welfare. Secondly, implementing energy-saving measures promotes sustainability and environmental responsibility, aligning with global efforts to combat climate change. Additionally, these initiatives can enhance the institution's reputation.

This study explores the feasibility of installing a 450 kWp solar photovoltaic (PV) system at ITUM to address rising energy costs and reduce dependency on non-renewable energy. Solar energy is an ideal solution, not only for lowering electricity bills but also for contributing to the sustainability goals of the country. By utilizing renewable energy, ITUM can reduce its carbon footprint, lower operational costs, and promote a culture of sustainability among students and staff. This investigation aims to provide actionable recommendations to meet a substantial percentage of the institution's daytime energy demand using solar PV systems, estimate financial savings from reduced electricity bills, and determine the reduction in carbon emissions.

2. METHODOLOGY

Past electricity bills of the institute were collected and analyzed to determine the monthly and annual energy consumption. Table 1 shows the average monthly consumption of electricity during off-peak time, daytime, and peak time. The electricity tariff charged by Ceylon Electricity Board and the corresponding cost of energy consumption during three time slots are also shown in Table I (Business With CEB, n.d.). Major consumers of the institute were identified as refrigeration and air conditioning systems. The air-conditioning system is operated solely in the administration buildings, some lecture halls and laboratories, and the auditoriums while student accommodations are not equipped with air conditioners.

Table 1. Monthly Energy Consumption in the Institute

Time of the Day	Current usage (kWh)	Tariff (Rs./kWh)	Cost of consumption (Rs.)
Off peak (2230 - 0530)	16,769	30.6	513,131.40
Day (0530 - 1830)	87,763	37.4	3,282,336.20
Peak (1830 - 2230)	20,930	45.9	960,687.00
Total	**125,462**		

The ITUM is located at a latitude of 6.7924° N and a longitude of 79.9641° E. The total surface area available in the institute for solar panel installations was identified by an analysis conducted using Google Earth (Google Earth, n.d.). The workable roof area was calculated to be over 5100 m^2. Figure 1 shows the view of the institute captured from Google Earth.

Fig.1. View of ITUM Captured from Google Earth

In our study, a 450 kWp system was selected which is equivalent in size to 80% of the roof area approximately. The extra amount of energy generated in holidays or university vacations can be exported to the national grid, though this was not considered in the payback time calculation due to the unpredictable nature of the university's schedule. Monthly savings from solar energy utilization and the simple payback period are calculated with the use of the data shown in Table 2 (Ceylon Eco Solar (Pvt) Ltd, n.d.). The payback period was calculated by dividing the cost of the investment by the savings or revenue produced. Reduce carbon footprint by offsetting the need for energy produced from fossil fuels was estimated.

Table 2. Data Collected to Estimate the Payback Period and Reduced Carbon Footprint

Description	Amount	Unit
Average daily peak sunlight hours in Homagama	5.3	h
Derating factor due to temperature	0.9	-
Inverter efficiency	0.9	-
Approximate unit cost for 48V batteries	6000	Rs/Ah
Tariff at which solar energy is purchased by CEB (*Business With CEB*, n.d.)	23.18	Rs/kWh
Emission factor (*Ceb.Lk/Publication-Media/Planing-Documents*, n.d.)	0.568	Kg CO_2/kWh

3. RESULTS AND DISCUSSION

According to the market survey, the approximate cost of solar PV systems (including inverter and other accessories) is 350 USD per kW (Ceylon Eco Solar (Pvt) Ltd, n.d., About Us - First Energy, n.d.). Accordingly, the total investment will be approximately 48.04 million LKR while 2.17 million LKR can be saved from the electric city bill. The payback period will be a maximum of two years. Table 3 shows summarized details. The estimated area occupied by the proposed system is 4183m^2 (45,000ft^2), if the area occupied by 1kW solar PV is 100ft^2 approximately (Solartechadvisor.Com, 2022). The installation of the solar energy system will reduce the institute's carbon footprint by 395 MT of carbon dioxide per year.

Sustainability should be addressed not only in energy management but also in curriculum development, administration, and reporting culture (Ramos et al., 2015). Academic institutions have the potential to mitigate their adverse environmental impact while concurrently cultivating a sustainable culture that will prepare forthcoming leaders to tackle global issues.

Table 3. Details on Estimated Payback Period

Description	Value	Unit
Installed Solar PV capacity	450	kWp
Expected monthly generation from solar	57956	kWh
Approximate unit cost of solar PV & Inverter	350	USD/kW
Dollar rate as at 07-09-2024 (*Exchange Rates | Central Bank of Sri Lanka*, n.d.)	305	Rs.
Total Investment	48.04	Rs. Million
Monthly savings from electricity bill	2.17	Rs. Million
Payback period	23	months
	2	years

4. CONCLUSION

The proposed installation of a 450 kWp solar photovoltaic (PV) system is expected to significantly reduce the electricity costs and carbon footprint of the institute. With a total investment of approximately 48.04 million LKR and an estimated simple payback period of two years, the system will generate around 57,796 kWh of electricity per month. 65 % of energy consumption will be covered during the daytime. Combined with a monthly savings of 2.17 million LKR on electricity bills, the financial viability of the project is well-supported. Furthermore, the project will have a significant environmental impact, reducing the institute's carbon footprint by 395 MT of CO_2 annually. Overall, the proposed solar pv system becomes an ideal solution for energy cost reduction of ITUM and the National energy crisis.

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