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Renewable energy education in engineering: an assessment on the use of solar photovoltaic systems in NSW and Victoria

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Abstract

Global demand for renewable energy has increased in the past few decades, which has escalated the importance of studying this subject in engineering education. Solar energy plays a pivotal role in meeting the demand of clean and sustainable energy and improving the stability of the energy system. This study investigates the state of solar energy adoption in New South Wales (NSW) and Victoria (VIC), Australia's two leading States, in terms of the users' perception and the economic impact of Solar Photovoltaic (SPV) systems in households. The Survey results from the SPV users highlight financial savings, environmental awareness and government incentives are the main drivers for adoption. Economic analysis shows, NSW has a higher monetary benefit from the installation of SPV systems than VIC, with shorter payback period (3.9 years for NSW and 6.3 years for VIC) and higher Return on Investment (approximately 317% for NSW and 156% for VIC). The Levelised Cost of Electricity (LCOE) has been calculated as $0.109 and $0.128 for NSW and VIC respectively, which indicates greater financial potential of SPV installation in NSW compared to VIC. These LCOE values have been estimated based on a common total present value of electricity generated over 25 years of lifetime of the SPV system, which has been 53,892.8 kWatt. Despite facing some challenges such as high initial costs or complex installation structures, both states have the potential to grow and take advantage of the benefits of solar energy. However, the diversity in local geographical conditions in the two states require appropriate strategies to overcome the challenges and create a more favorable environment for further deployment of solar energy.

Keywords*:* Solar photovoltaic system, survey, return on investment, levelised cost of electricity

1. INTRODUCTION

Over the last few decades, global demand for clean and renewable energy has increased due to climate change and environmental pollution problems. Renewable energy education in engineering explores the best ways to make use of renewable energy technologies, such as solar thermal systems, photovoltaics, hydroelectric, wind and biomass. In 2019-20, solar, wind, and hydroelectric together contributed 222 petajoules to Australia's domestic energy supply, marking a 15% increase from 2018-19 and continuing the upward trend observed over the past five years (ABS 2021). Solar energy plays a vital role in meeting the demand of renewable energy, reducing emissions and improving the stability of the energy system. Australia is known as one of the countries with the most abundant solar energy resources in the world. Globally, Australia is ranked second in the rate of solar installations per capita, with 150 watts installed per person in 2022 (AEC 2023). In 2021 alone, solar energy accounted for 11.7% of the country's electricity output, reflecting stable annual growth on installed solar capacity (DCCEEW 2022).

New South Wales (NSW) and Victoria (VIC) are Australia's two largest states, with large populations and high energy demand. Rapid population and industrial growth in both states create a need to evaluate and to understand the use of solar energy especially in the household sector, where the amount of end use of energy is maximum (ABS 2021). Increasing the use of solar photovoltaic (SPV) system at the household level not only helps relieve pressure on the national electricity system but also contributes to Australia's sustainable development goals and carbon emission reduction. This study aims to comprehensively assess the current situation of solar energy use by households in NSW and VIC, the perceptions of solar energy users and the economic impact of SPV systems.

2. MATERIALS AND METHODS

In this research, a survey was conducted via Google Forms and distributed to randomly selected households in NSW and VIC via email and online platforms. The survey gathered information using a Likert scale from 25 participants from households in NSW and VIC to provide a comprehensive view of solar energy adoption trends and influencing factors in these regions. The questionnaire was designed to collect information on respondents' demographic information and their perception on the installation of SPV systems in terms of their level of satisfaction and environmental awareness for adoption.

This study also used secondary data on historical electricity consumption in NSW and VIC to evaluate the effectiveness of SPV systems in reducing energy consumption and generating cost savings. The secondary data collection process involved sourcing key parameters related to solar panel installations in NSW and VIC. This includes gathering information on panel size, costs, energy usage, savings, and payback periods (Sykes 2023a and 2023b). These parameters are important to evaluate the economic feasibility of using solar energy and guide consumer decision-making about solar panel installation. The data collected was comprehensively analysed to evaluate the financial outcomes of solar adoption in NSW and VIC, which assist consumers in making smart decisions about SPV system installation. Standard calculation methods were used to determine key economic parameters, which are listed in Table 1.

Table 1. Standard calculation methods for determining key economic parameters

Parameter	Equation	Source
Return on Investment (ROI)	$\textbf{ROI\%} = \left(\frac{\text{Net Profit from Investment}}{\text{Total Cost of Investment}}\right) \times 100$	Fernando 2022
Levelized Cost of Electricity (LCOE)	$\text{LCOE} = \frac{\text{Total Present Value of Costs}}{\text{Total Present Value of Electricity Generated Over the Life Time}}$ $\text{Total present value cost} = \text{Initial Investment} + \sum \frac{\text{Maintenance Cost}}{(1+\text{discount rate})^{\text{time}}}$	CFI 2023

3. RESULTS AND DISCUSSION

3.1 Survey Questionnaire Analysis

3.1.1 Demographic Profile

Survey participants (n= 25) were 56% from NSW and 44% from VIC who represented a diverse range in demographics. The majority of participants were male (60%) compared to female (36%). The 31-40 age group was the largest segment (52%) of the respondents, followed by the 20-30 (40%) and 41-50 (less than 10%) age group. The household income of the largest segment (40%) earns between $30,000-$50,000, followed by 28% in the $50,000-$75,000 range, and 24% reported income below $30,000.

The demographic data shows strong interest in solar energy among the 20-40 age group, promising great adoption potential in the future. Among the participants, 64% reported having SPV systems installed on their homes, while 36% did not. This distribution shows the differences in solar energy adoption and serves as a foundation for further analysis of adoption trends and influencing factors.

3.1.2 Factors affecting solar power adoption

Figure 1 shows that financial savings were the main reason for choosing solar energy, with 93.8% of respondents citing it, emphasizing the important role of economic factors. In addition, environmental concerns (25%), incentives from the government (18.8%), and the desire for energy independence (25%) have also influenced the decision to use solar energy. These results directly address the research question about the factors driving solar energy adoption. Further, the results are important in informing targeted strategies to promote sustainable energy transitions in line with the objectives of the research.

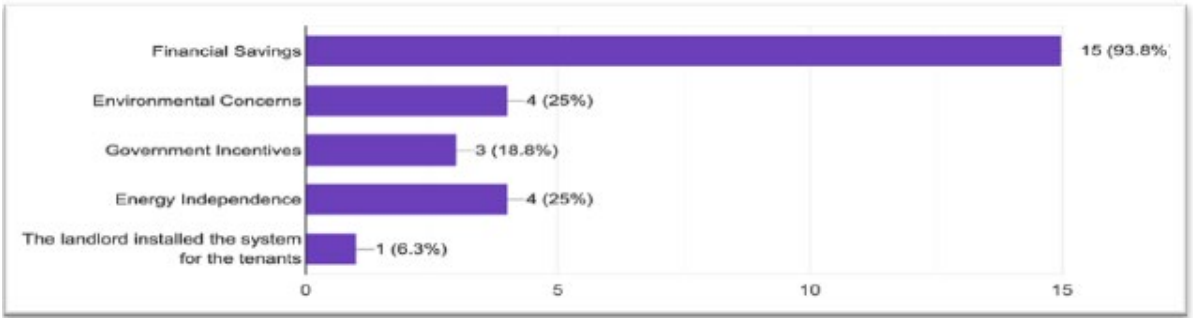

Figure 1. Solar Power Adoption Factors

3.1.3. Satisfaction and Impact

Based on the data presented in Figure 2, both NSW and VIC show high user satisfaction with solar energy. The difference of results between the states may be due to specific factors in policy, natural conditions, or cultural factors in each region, but overall, both have positive user acceptance of solar technology. Nevertheless, roof structure, high initial costs and difficult approval processes emerge as some key barriers in installation of SPV systems in both states.

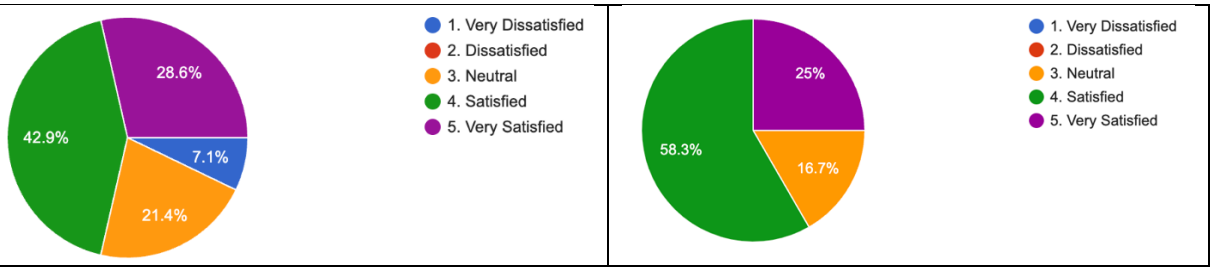

Figure 2. Level of satisfaction with SPV system in NSW and VIC

Solar panel installations have had a significant impact on energy consumption patterns in NSW and VIC as shown in Figure 3. In NSW, the proportion of users reporting a reduction in energy consumption was 85.7%, while in VIC the proportion was 75%. The reduction in energy consumption in households with solar power systems installed can reach up to 30 to 50%. This not only helps decrease annual electricity bills by reducing the amount of electricity drawn from the grid, but also creates additional economic benefits as users are paid for the electricity exported to the grid from their SPV systems.

3.1.4 Environmental awareness

The information presented in Figure 4 emphasises the recognition of solar energy as a renewable and environmentally friendly source compared to traditional fossil fuel-based energy sources among the respondents. A significant percentage of respondents expressed their awareness on the environmental benefits of SPV systems. This indicates that people's perception on solar energy plays an important role in significantly reducing carbon emissions and environmental degradation, contributing to efforts to mitigate global climate change.

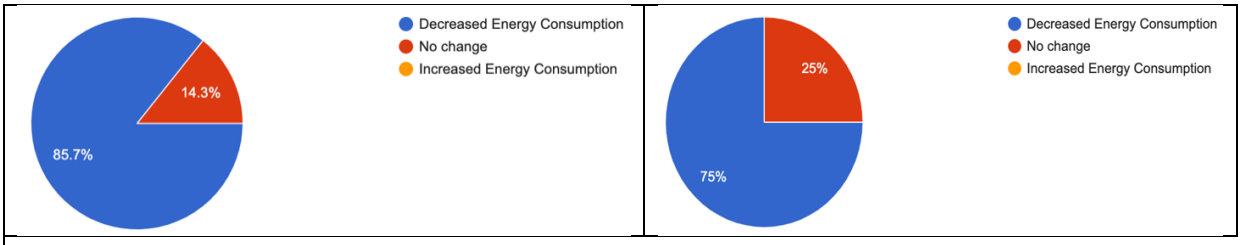

Figure 3. Effects of SPV installation on energy consumption patterns in NSW and VIC

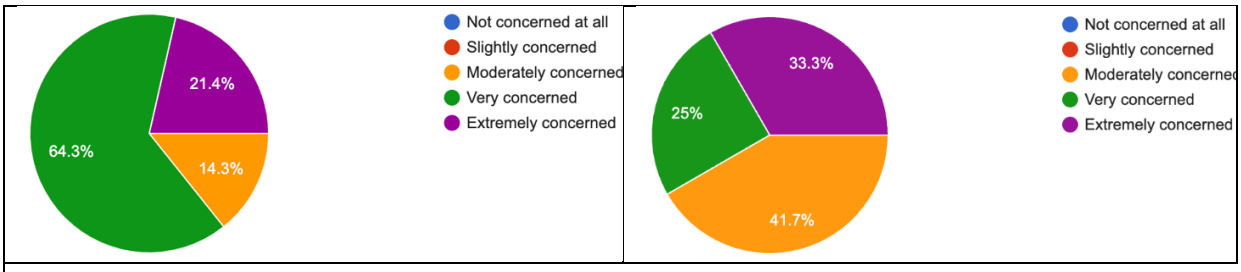

Figure 4. Environmental awareness regarding SPV systems in NSW and VIC

3.1. Economic analysis

Table 2 presents the average installation data of SPV systems in NSW and VIC that have been used for calculating ROI and LCOE. There are differences in costs, savings and payback time of SPV installation in the two states, while the panel size and energy consumption remain the same. These differences reflect the variations in government incentives, energy prices and installation costs between the two states.

Table 2. Installation data of SPV in NSW and VIC

Parameter	NSW	VIC
Average Solar Panel Size	6.6 kW	6.6 kW
Average initial cost (after rebate)	$5,140	$6,030
Average daily Energy usage (kWh)	20 kWh	20 kWh
Annual Savings	$1,285	$927
Payback period	3.9 years	6.3 years

Adapted from: Sykes 2023a and 2023b

The ROI calculations for households in NSW and VIC are summarised in Table 3, which has been conducted based on an assumed maintenance cost of 2% of the initial investment per year. Such economic analysis over a 25-year period shows SPV systems create a significant positive financial impact for households in both NSW and VIC. Households in NSW achieved a higher ROI, which is 316.66%, compared to 156.22% in VIC. This difference mostly comes from lower initial installation costs and higher annual savings in NSW, resulting in greater net returns over the life of the system. Financial benefits in NSW are further enhanced by favorable solar conditions and higher electricity prices, which increase annual savings through reduced electricity bills.

Table 3. ROI results for SPV systems in NSW and VIC

Parameter	NSW	VIC
Annual maintenance cost (2% of Initial cost)	$102.8	$120.6
Total maintenance cost over 25 years	$2,570	$3,015
Total cost of investment (initial cost + maintenance cost)	$7,710	$9,045
Total savings over 25 years	$32,125	$23,175
Net Profit (total saving – total cost of investment)	$24,415	$14,130
ROI	316.66 %	156.22%

Incentive and financial support programs in both states play an important role in enhancing the financial attractiveness of solar power systems. Programs such as the Solar Loan Scheme and the Small Scale Renewable Energy Scheme in NSW, along with the Solar Homes Scheme and the Victorian Energy Upgrade Scheme, possibly helping to significantly reduce initial investment costs, thereby improving ROI. Despite ongoing maintenance costs, which are estimated to be 2% of the initial investment annually, the overall financial benefits from solar PV systems far outweigh these costs. So households in both states can expect significant savings and net returns over the course of 25 years.

Table 4. Results on Levelised Cost of Electricity Analysis

State	Initial cost after rebate	Discount rate	Life span (years)	Total present value of cost	Total electricity generated over 25 years	Total present value of electricity generated over life time	LCOE (per kWh)
NSW	$5,140	5%	25	$\$5140 + \sum_{t=1}^{25} \frac{0.02 * 5{,}140}{(1+0.05)^{25}}$ = $5,898	20 kWh/day * 365 days/year * 25 years = 182,500 kWh	$\frac{182{,}500\ kWh}{(1+0.05)^{25}}$ = 53, 892.8 kW	$0.109
VIC	$6,030	5%	25	$\$6030 + \sum_{t=1}^{25} \frac{0.02 * 6030}{(1+0.05)^{25}}$ = $6,920	182,500 kWh	53, 892.8 kW	$0.128

Furthermore, the results on LCOE analysis have been presented in Table 4. The relatively lower LCOE value of NSW in comparison to VIC indicates greater financial potential of SPV installation in NSW compared to VIC. This suggests that installing SPV systems in NSW may yield greater financial benefits than in VIC. This also reflects the influence of policy and geographical conditions (especially solar radiation) in the selected states. In addition, some other factors such as weather conditions, transportation costs, and technical limitations that need to be considered for better understanding the performance of SPV systems, which underscores the importance of further studying on renewable energy in engineering education.

4. CONCLUSIONS

This study comprehensively evaluates the adoption and impact of solar energy in Australian households, combining survey questionnaires and secondary data analysis or NSW and VIC. Survey results show high levels of satisfaction among solar users in both states, with 71.5% of users in NSW and 83.3% in VIC reporting a 'high level of satisfaction' or a 'satisfaction'. Solar panel installation has had a significant impact on energy consumption patterns, with 85.7% of NSW users and 75% of VIC users reporting a reduction in energy consumption. Economic analysis shows SPV installations deliver significant benefits in both states, with NSW having a shorter payback period of 3.9 years with a high ROI value of 316.66% in 25 years. Besides, VIC has a payback period of 6.3 years and a ROI of 156.22% over the same period. These differences are due to lower installation costs and higher annual energy savings in NSW compared to VIC. Financial incentives and rebates play an important role in enhancing the financial viability of solar installations, making them an attractive investment despite the higher initial costs in VIC. In summary, the study highlights the importance of adopting appropriate approaches to encourage the use of solar energy and facilitate its wider deployment. By leveraging financial incentives, increasing awareness of environmental benefits, and simplifying approval processes, policymakers and stakeholders can promote sustainable energy transitions and protect the environment in both NSW and VIC.

5. ACKNOWLEDGMENTS

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