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Strategic Feasibility Analysis for Implementing Solar-Powered Electric Vehicle Charging Infrastructure at Universitas Pendidikan Indonesia Bumi Siliwangi Campus Using SWOT Approach

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ABSTRACT

The increasing adoption of electric vehicles (EVs) in Indonesia requires the development of sustainable charging infrastructure to support emission reductions and national renewable energy targets.

Background. This study addresses the lack of solar-powered EV charging stations in higher education institutions, particularly at Universitas Pendidikan Indonesia (UPI) Bumi Siliwangi Campus.

Methods. A descriptive research design combined primary data through questionnaire surveys and secondary data from related literature. The SWOT analysis method was applied to identify internal strengths and weaknesses, as well as external opportunities and threats, to assess the feasibility of the proposed system.

Results. The findings indicate that UPI has significant internal strengths, such as solar energy potential, green campus initiatives, supporting infrastructure, and an active academic community. Key weaknesses include high investment costs and system maintenance complexity. Externally, opportunities include government policy support and rising public awareness, while threats involve price fluctuations and policy uncertainties. The SWOT matrix positions the strategy in Quadrant II (aggressive), recommending Strengths-Opportunities (SO) strategies.

Conclusion. The study concludes that implementing solar-powered EV charging stations at UPI is strategically feasible and can serve as a national model. It supports clean energy transitions and enhances the university's image as a green campus. Future research should consider techno-economic simulations and long-term monitoring.

1. INTRODUCTION

As one of the countries with a high level of vehicle use, based on a survey by the Central Statistics Agency (BPS) of Indonesia in 2020, Indonesia has 136,127,451 vehicles (Badan Pusat Statistik, 2020). This causes the transportation sector to absorb 44.2% of Indonesia's total national energy consumption in 2021 (Sekretariat Jenderal Dewan Energi Nasional (DEN), 2022). Along with that, the use of oil and fuel for the transportation sector has also increased and, of course, has an impact on the environment in the form of climate change.

Along with the increasing global awareness of climate change, using electric vehicles (EVs) is considered a sustainable option for environmentally friendly transportation because it does not use fossil fuels and can reduce carbon emissions and the potential for climate change (Lelieveld et al., 2019). Currently, there are challenges in using electric vehicles in Indonesia, one of which is the dependence on electric vehicle charging stations (EV charging), which still needs to be improved (Huang & Kockelman, 2020). Therefore, if an electric vehicle charging station is in a location, that location tends to increase the number of electric vehicle users (Lokhandwala & Cai, 2020).

Indonesia is currently included in the ranks of countries that support and adopt the Sustainable Development Goals (SDGs), including implementing various education programs (Rulandari, 2021). Universities play a strategic role in realizing the SDGs because they can act as change agents and pioneers in implementing sustainable development practices (Peraturan Presiden Republik Indonesia, 2020). Universities have great potential to promote and support the achievement of SDGs through various initiatives, such as green campus development, environmentally friendly operations, research related to sustainability issues, community involvement, and social responsibility.

As an educational institution committed to sustainability, Universitas Pendidikan Indonesia (UPI) strives to become a green campus by implementing environmentally friendly technology. One such initiative is building solar-based EV charging stations. Thus, a green ecosystem of electric vehicles with resources originating from solar-based charging stations will form.

Although solar energy has various benefits, technical and financial challenges in implementation still need to be considered. Factors such as initial investment costs, land requirements for solar panel installations, and the availability of policy and infrastructure support are essential to evaluate. Therefore, this study uses the strength, weakness, opportunity, and threat (SWOT) analysis approach to break down existing problems into smaller parts that appear more straightforward than implementing a solar-based EV charging system at the UPI Bumi Siliwangi campus (Rahmayati, 2015). This study is expected to provide strategic recommendations for UPI in improving green infrastructure and contributing to achieving renewable energy targets in Indonesia. With this study, UPI can also be an example for other educational institutions adopting renewable energy technology.

2. METHODS

This study used a descriptive approach that combines qualitative and quantitative methods to evaluate the feasibility of implementing a solar-based electric vehicle charging station at the Universitas Pendidikan Indonesia (UPI) Bumi Siliwangi campus. This study used two types of data: primary and secondary. Primary data was obtained by conducting a

questionnaire survey of parties in the UPI Bumi Siliwangi campus environment, ranging from students, lecturers, employees, and infrastructure officers to alumni. The questionnaire was based on direct field observations and secondary data from literature studies from related research journals, such as green campuses, renewable energy, electric vehicle infrastructure, EV charging, and national and international energy policies. Secondary data is also needed to identify this project's internal and external factors. The questionnaire survey results were then analyzed to determine the SWOT position matrix based on the IFAS (Internal Strategic Factor Analysis Summary) and EFAS (External Strategic Factor Analysis Summary) tables. Using a strategy diagram, the table shows the right strategies to evaluate the feasibility of implementing solar-based electric vehicle charging stations at the Universitas Pendidikan Indonesia (UPI) Bumi Siliwangi campus. Four possible strategies will be obtained, namely the S-O (Strength-Opportunity) strategy, which takes advantage of opportunities by using strengths; the S-T (Strength-Threat) strategy, which uses strengths to prevent threats; the W-O (Weakness-Opportunity) strategy, which takes advantage of opportunities by minimizing weaknesses; and the W-T (Weakness-Threat) strategy, which avoids threats and minimizes weaknesses (Karlina, 2015). Then, the data that has been collected is analyzed using a SWOT matrix for each factor (internal and external) that can evaluate the implementation plan of this project, both in terms of internal factors (strengths and weaknesses) and external factors (opportunities and threats). The analysis results of internal and external factors are then used to formulate strategies that follow the conditions and potential of the UPI Bumi Siliwangi campus. The conclusions in this study are drawn based on the analysis results that connect the SWOT findings with UPI's sustainability goals. The methods in this research can be seen briefly in the research flow diagram in Figure 1.

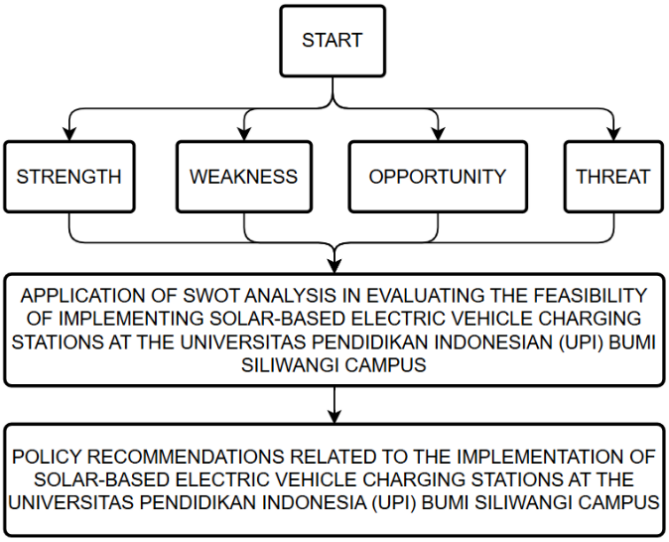

Figure 1. Research Flow Diagram

3. RESULTS AND DISCUSSION

RESULTS

3.1 Identification of SWOT Criteria

Identification of the criteria for strengths, weaknesses, opportunities, and threats to the implementation of the construction of solar-based electric vehicle charging stations is based on data and information from several related publications.

3.1.1 Strengths

a. High potential for solar energy at UPI Bumi Siliwangi campus
The UPI Bumi Siliwangi campus, located in Bandung City, West Java, has a solar

b. Support for a green campus and sustainability from UPI
As Indonesia's most significant educational campus, UPI's role in encouraging sustainability and a green campus is much needed (Peraturan Presiden Republik Indonesia, 2020).

c. Potential for education and research for students
With this implementation, it will be able to help with learning and research for the campus community (Peraturan Presiden Republik Indonesia, 2020).

d. Supporting campus infrastructure
Several buildings at the UPI Bumi Siliwangi campus have installed PLTS.

e. Supporting research and education laboratories
There is a Renewable Energy Engineering study program at the Faculty of Engineering and Industrial Education, with several laboratories focusing on renewable energy.

f. The existence of an internal community that supports the development of solar technology
A student community, namely the Society of Renewable Energy (SRE) UPI branch, promotes renewable energy, such as solar energy.

3.1.2 Weaknesses

a. High investment costs
The costs required for investment in solar energy systems and EV charging are still high (Wang et al., 2020).

b. Dependence on the weather for energy production
Solar energy cannot be separated from the influence of weather in its energy production (Hidayanti, 2021).

c. Significant routine maintenance needs
A complex system of solar-based EV charging will also require complex maintenance (Oladigbolu et al., 2022).

d. Complexity of licensing and procurement processes
To operate a system connected to the national electricity grid, a permit must be issued

by the relevant agency, which is complex and not straightforward (Zuhaid, 2024).

e. Resistance to change from several UPI policymakers
In energy politics, every policy issued by policymakers will affect the development of renewable energy (Mudhoffar & Magriasti, 2024).

f. The need for experts to manage the system
The system's complexity creates a need for personnel with expertise in its management to operate optimally (Oladigbolu et al., 2022).

3.1.3 Opportunities

a. Government policy support for renewable energy and EVs
The government has issued various policies and plans encouraging renewable energy development (Pemerintah Daerah Provinsi Jawa Barat, 2019; Pemerintah Republik Indonesia, 2017).

b. Potential collaboration with renewable energy companies and EV manufacturers
In developing technology, the academic and industrial worlds must collaborate to produce products for the market (Pacheco et al., 2019).

c. Technological advances in solar panel efficiency and EV chargers
Renewable energy technology has developed rapidly (Hemavathi & Shinisha, 2022).

d. Fiscal incentive support for renewable energy projects
To support the development of renewable energy in the world, many fiscal incentives are already available for projects related to renewable energy (Qadir et al., 2021).

e. Improvement of campus image in green campuses
The increasing application of renewable energy in the campus environment will improve the image of the campus as a green campus (Peraturan Presiden Republik Indonesia, 2020).

f. Trend of increasing public awareness of sustainability
Public awareness of sustainability, especially renewable energy use, has increased (Awan et al., 2022).

3.1.4 Threats

a. Price fluctuations in solar panel and EV charger technology
The technology in solar panels and EV chargers continues to develop with increasing demand, causing price fluctuations in the market (Huang et al., 2024).

b. Risk of changes in government policy
Changes in government policy significantly impact the implementation of renewable energy, which can support or hinder (Mudhoffar & Magriasti, 2024).

c. Potential damage due to extreme weather
Because the system is outdoors, the possibility of system damage due to extreme weather always exists (Bošnjaković et al., 2023).

d. Equipment safety issues in open environments

The security of system equipment must be a concern because the location is in an open area, both from humans, animals, and electronics (Dimitriadou et al., 2023).

e. Potential challenges in managing electronic waste

Electronic waste must also be a concern to support sustainability (Rene et al., 2021).

f. Uncertainty in community response to new technologies

The presence of new technology in the environment gives rise to various positive and negative public responses (Muttaqee et al., 2023).

3.2 SWOT Strategy Analysis

3.2.1 Internal Strategic Factor Analysis Summary (IFAS)

The following is an IFAS table based on the results of a questionnaire survey by 44 respondents to determine the weight and rating of each internal criterion, namely strengths and weaknesses.

Table 1. Internal Strategic Factor Analysis Summary (IFAS)

	Strategic factor	Weight	Score	Weight x Score
	Strength			
S1	High potential for solar energy at UPI Bumi Siliwangi campus	0.081	3.86	0.314
S2	Support for a green campus and sustainability from UPI	0.085	4.20	0.358
S3	Potential for education and research for students	0.088	4.09	0.359
S4	Supportive campus infrastructure	0.085	3.80	0.323
S5	Supportive research and education laboratories	0.084	3.68	0.310
S6	The existence of an internal community that supports the development of solar technology	0.083	3.73	0.308
	Total Strength	0.506	23.36	1.972
	Strategic factor	Weight	Score	Weight x Score
	Weakness			
W1	High investment costs	0.080	3.89	0.311
W2	Dependence on weather for energy production	0.081	3.91	0.316
W3	Significant routine maintenance needs	0.089	4.05	0.361
W4	Complexity of licensing and procurement processes	0.081	3.77	0.307
W5	Resistance to change from some UPI policymakers	0.078	3.55	0.276
W6	Need for expert staff for system management	0.085	4.02	0.340
	Total Weakness	0.494	23.18	1.911
	Total Internal	1.000	46.55	3.883

3.2.2 External Strategic Factor Analysis Summary (EFAS)

The following is an EFAS table based on the results of a questionnaire survey by 44 respondents to determine the weight and rating of each external criterion, namely opportunity and threat.

Table 2. External Strategic Factor Analysis Summary (EFAS)

	Strategic factor	Weight	Score	Weight x Score
	Opportunity			
O1	Government policy support for renewable energy and EVs	0.085	3.95	0.335
O2	Potential collaboration with renewable energy companies and EV manufacturers	0.082	3.95	0.326
O3	Technological advances in solar panel efficiency and EV chargers	0.086	3.98	0.340
O4	Fiscal incentive support for renewable energy projects	0.082	3.80	0.311
O5	Improvement of campus image in green campuses	0.088	4.25	0.375
O6	Trend of increasing public awareness of sustainability	0.085	3.98	0.337
	Total Opportunity	0.507	23.91	2.023
	Strategic factor	Weight	Score	Weight x Score
	Threat			
T1	Price fluctuations in solar panel and EV charger technology	0.078	3.82	0.299
T2	Risk of changes in government policy	0.077	3.66	0.281
T3	Potential damage due to extreme weather	0.083	3.91	0.325
T4	Equipment safety issues in open environments	0.086	4.14	0.358
T5	Potential challenges in managing electronic waste	0.089	4.09	0.363
T6	Uncertainty in community response to new technologies	0.079	3.68	0.291
	Total Threat	0.493	23.30	1.917
	Total External	1.000	*47.20*	*3.941*

DISCUSSION

Based on the analysis of Table 1 and Table 2, each strength, weakness, opportunity, and threat score value is:

a. Strength Score = 1.972

b. Weakness Score = 1.911

c. Opportunity Score = 2.023

d. Threat Score = 1.917

Based on the data above, the SWOT strategy analysis diagram is determined by identifying the points of various strategies: SO, ST, WT, and WO. These points are based on the criteria score, provided that the weakness and threat scores are subtracted because of things that hinder. So that the strategic points in this study are as follows:

a. S-O Strategy: (2.023; 1.972)

b. S-T Strategy: (-1.917; 1.972)

c. W-T Strategy: (-1.917; -1.911)

d. W-O Strategy: (2.023; -1.911)

The display of the SWOT analysis strategy diagram is shown in Figure 2

Based on the results of the comparison between internal and external factors in the SWOT analysis strategy diagram above, the strategic position, namely the aggressive position, is in quadrant II.

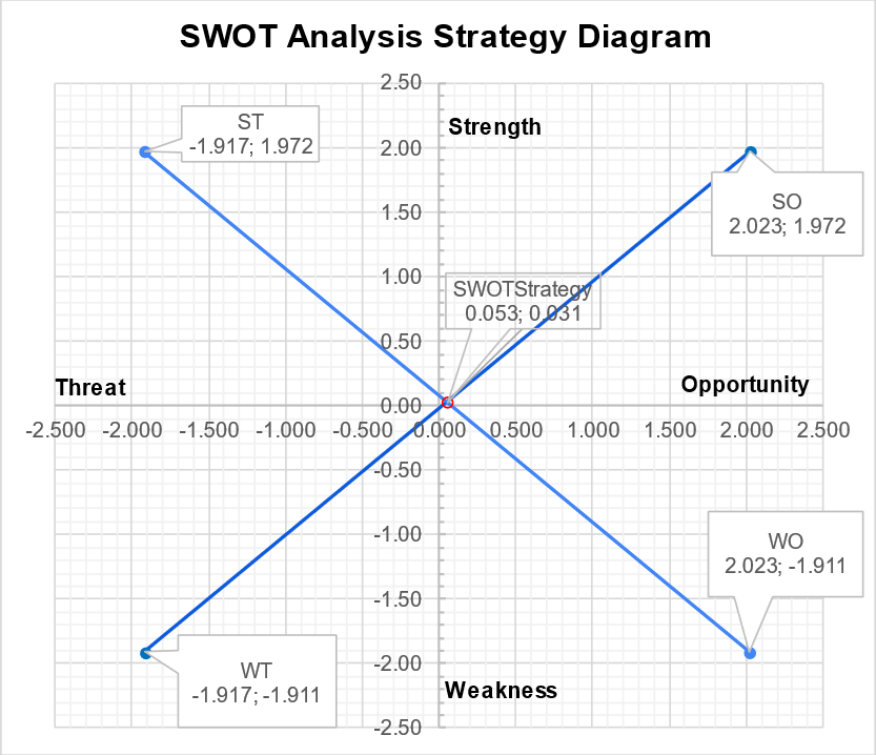

Figure 2. SWOT Analysis Strategy Diagram

4. CONCLUSION

Universitas Pendidikan Indonesia (UPI), the parent of educational campuses in Indonesia, has an important role in developing sustainability and renewable energy for other educational campuses. One effort that can be made is implementing an electric vehicle charging station based on solar energy in its campus environment, which can be started from the Bumi Siliwangi campus.

The SWOT analysis results for the potential implementation of an electric vehicle charging station based on solar energy at UPI Bumi Siliwangi campus show that, from an internal perspective, the strengths of the potential are greater than the weaknesses. While from an external perspective, the potential opportunities are greater than the threats. So, the appropriate strategy for implementing an electric vehicle charging station based on solar energy at UPI Bumi Siliwangi campus is to use its strengths to capture existing opportunities.

The strategic position in quadrant II, namely the aggressive position, shows that the most appropriate strategy for implementing an electric vehicle charging station based on solar energy at UPI Bumi Siliwangi campus is an aggressive strategy based on the Strengths and Opportunities (SO) criteria. For this reason, the recommendations given are several strategies

developed based on the SO criteria, including:

a. Using the potential of solar energy at UPI Bumi Siliwangi Campus as a national pilot model to support the implementation of government policies related to renewable energy and electric vehicles.
b. Utilizing the Renewable Energy Engineering study program and research laboratories to collaborate with renewable energy companies and EV charger manufacturers in technology development and testing.
c. Making this installation part of the green campus branding can enhance UPI's image as a sustainability pioneer in Indonesia.
d. Adopting the latest technology in solar panels and EV charger efficiency to ensure that the installed system is relevant to user needs and friendly to future technological changes.
e. Utilizing the trend of increasing public awareness of sustainability to involve students, staff, and the surrounding community in this project.
f. Make this project a case study or implementation model that other universities in Indonesia can adapt to.

The aggressive strategy leverages existing strengths to take maximum advantage of external opportunities. In this case, the Strengths and Opportunities (SO) based strategy ensures the project has a strong technical, financial, and social foundation. By utilizing the potential of solar energy and government policy support, UPI meets the need for environmentally friendly energy and enhances its reputation as a leading green campus.

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