Solar-assisted Mobile Pet Grooming Services: A Sustainable Entrepreneurship Model for Green Innovation

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Abstract*– In Honduras, the pet market is growing steadily. This is driven by increasing consumer awareness about the welfare of pets along with the need for convenience and personalized services. The growth of pet services has generated a greater demand for innovative solutions that can meet the customer needs. However, the traditional model based on fixed locations has limitations related to mobility, location, time, and customer convenience. Taking advantage of this market opportunity and the availability of renewable resources in the country, this research analyzes the feasibility of a solar-assisted mobile pet grooming vehicle as a sustainable entrepreneurial solution. The study includes the sizing of the photovoltaic system with energy storage for a vehicle using SAM. Its return on investment is analyzed, yielding a payback of 15 months. Due to limited space in the vehicle, only one solar panel was installed, yielding an average daily generation of 1.07 kWh/day over the 10-day monitoring period contributing with the energy requirements of the operation. The findings highlight the potential of renewable energy technologies to support innovative and environmental awareness in businesses. This work lays the groundwork for adaptable and sustainable business models that evolve according to market demand and go hand in hand with environmental stewardship and innovation.

***Keywords--Green Innovation, Mobile Pet Grooming, Renewable Energy*, Sustainable Entrepreneurship, Techno-Economic Analysis.**

I. INTRODUCTION

In Honduras, grooming services are primarily provided at brick-and-mortar locations, typically in shopping malls, where the traditional business model requires pet owners to bring their pets to the facility and adjust their schedules to match the business hours. This model presents certain logistical limitations, primarily related to transporting pets and the availability of customers' schedules. Furthermore, there are issues related to the safety and well-being of pets; in many establishments, it is very common for pets to be mishandled during the grooming process, which in turn typically increases the risk of stress and physical abuse. These factors can affect the pet's physical and emotional health and, consequently, the quality of the service. Moreover, there are ongoing operational costs inherent to the business model, such as commercial rent, rising electricity costs, and the difficulty of expanding the service. Additionally, the goal is to bring the service directly to the location most convenient for the customer, eliminating the need to travel to a commercial location, and providing safety and comfort while ensuring personalized and attentive care.

It has been found that pet owners do acknowledge that there are barriers to grooming their pets. First, they consider grooming to be an important part of pet care. [1] shows that 89% of the participants in its study indicated that grooming is important or very important for their pets' health and well-being. In addition, 92% of respondents reported at least one barrier to properly maintaining their pets' grooming. Furthermore, 46% reported three or more barriers simultaneously.

These barriers include cost, time, transportation, and the location of grooming facilities. In this context, a mobile vehicle that provides grooming services, whether at homes or other locations of interest to the customer, eliminates these barriers. In this way, customer convenience and pet well-being are ensured. This presents itself as a convenient potential solution for mobile grooming businesses.. Furthermore, it goes hand in hand with a sustainable solution that takes advantage of the renewable energy resources provided by the environment.

In addition, Honduras has significant potential for photovoltaic solar energy, which is even growing year after year in the residential sector due to its many advantages [2], [3]. The country has high solar energy potential, with an average of

5.27 kWh/m², thanks to its geographic location and the levels of solar radiation found in most of its departments.

According to the Ministry of Energy [4], it states that, because it is located in the intertropical zone, which encompasses the band of the planet between the Tropic of Cancer (approximately 23.5° N) and the Tropic of Capricorn (approximately 23.5° S), this region receives the highest levels of solar radiation consistently throughout the year compared to other countries around the globe. Based on the above according to statistics, Honduras has a constant supply of solar radiation, making it an ideal location for the implementation of solar energy systems.

Several articles have examined similar issues around the world. The ASPCA analyzed more than 50,000 animal care records to assess how access to grooming services and supplies affects animal welfare. They concluded that improving access to these services has a positive impact on pets' health [5]. Recent studies of the mobile pet care market

have analyzed in-home models for grooming and veterinary services [6]. Companies such as Groomit have developed mobile apps to schedule in-home grooming services, manage appointments, and connect pet owners with certified groomers [7]. Like these studies, this research aims to investigate the technical and economic feasibility of a solar-assisted mobile vehicle to provide these services. This approach can be considered innovative because it seeks sustainable solutions while still providing a high-quality service and adapting to customers' needs.

The rest of the article is organized as follows: Methodology, which clearly explains how the solar and energy storage systems were sized, along with the financial analysis. This is followed by the Results and Analysis section, where the most important findings of the research will be presented. Finally, the Conclusions section summarizes the main findings of the research.

II. Methodology

In this section, the methods for this research are explained. Figure 1 explains the step by step of the methodology.

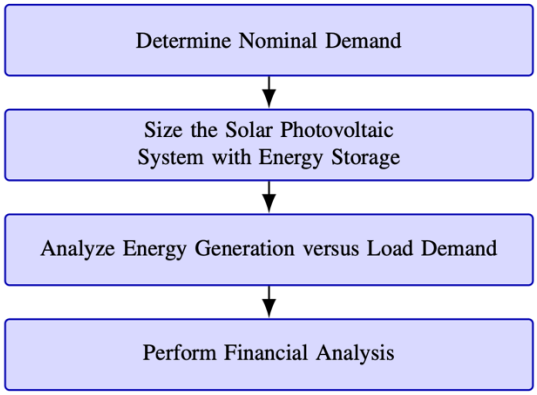


Fig. 1 Research Methodology Flowchart

A. Determine Nominal Demand

To determine the load capacity of the mobile vehicle, and inventory of all equipment the vehicle carries for grooming services was conducted. Table I shows a form used to tally the loads.

TABLE I
Electrical Load Inventory

Quantity [-]	Equipment [-]	Voltage [V]	Current [A]	Power [W]	Time of use [h]

With this information, a load profile was created using the power for each hour on the y-axis and time on the x-axis.

B. Size of the solar photovoltaic system with energy storage

To begin sizing the solar system, we must consider the available space on the vehicle's roof.

Next, solar irradiance data for San Pedro Sula are collected using data from the Global Solar Atlas and the minimum irradiance value to perform a conservative calculation. This data is necessary to calculate peak sun hours, as shown in Equation 1.

$$PSH = \frac{Rad_{\min}[\frac{kWh}{m^2}]}{1[kWh/m^2]} \quad (1)$$

Where:

- PSH = Peak Sun hours measure in [h]
- Rad_{min} = minimun radiation recorded according to the data collect [kWh/m^2]

Using Table I and the electrical load inventory, the daily energy requirement is calculated based on the power of the appliances and their estimated usage time. This data is necessary to calculate the sizing of solar modules based on the average daily energy consumption using Equation 2.

$$PV_p = \frac{E_{daily}}{PSH \times PR} \quad (2)$$

Where:

- PV_p = Photovoltaic power [kW]
- E_{daily} = Daily energy consumption [kWh]
- PSH = Peak sun hours [h]
- PR = Performance Ratio [-]

Because the roof area of vehicles is limited, this variable will determine the number of photovoltaic solar modules to be installed. In order to calculate the capacity of the battery bank, it is important to define the characteristics of the batteries to be used. The characteristics of the batteries to be used are as follows:

- System operating voltage [v]
- Capacity [Ah]
- Minimum runtime (1 day)
- Depth of discharge [%] (90%)

Using Equation 3 the battery bank capacity was calculated:

$$B_C = \frac{E_{daily} \times N}{V \times D_{pmax} \times F_{tc}} \quad (3)$$

Where:

- Bc = Battery capacity [Ah]
- E_{daily} = Daily energy consumption [kWh]
- N = Number of autonomy days [-]
- V = Nominal voltage of the system [V]
- D_{pmax} = Maximum percentage of discharge of the battery [%]
- F_{tc} = Themal compensation factor [-]

To size the inverter, take the total capacity of the photo-voltaic solar modules to be installed (which depends on the available space and the load analysis performed) and add an oversizing factor of 50%. Next, the charge controller was calculated based on the power of the solar modules and the battery bank voltage using the equation 4.

$$I_{max} = \frac{PV_p}{V_b} \quad (4)$$

Where:

- I_{max}= Maximum intensity of the controller [A]
- P_{Vp} = Maximum power of photovoltaic modules [kW]
- V_b = Battery system voltage [V]

$$V_{oc} = N \times V_{ocp} \quad (5)$$

Where:

- V_{oc} = Maximum open-circuit voltage of the solar system [V]
- N = Number of solar panels in a string
- V_{ocp} = Open-circuit voltage from the solar module [V]

The calculation of the Battery Bank Discharge Capacity was made following Equation 6.

$$E_{ext} = \frac{E_c}{\eta_i} \quad (6)$$

Where:

- E_{ext} = Energy extracted from Battery Bank [Wh]
- E_c = Daily energy consumption from charges [Wh]
- η_i = Inverter efficiency [%]

Next, the total energy of the battery bank was calculated using the Equation 7:

$$E_{total} = V_s \times B_c \quad (7)$$

Where:

- E_{total} = Total energy capacity of the battery bank [Wh]
- V_s = Voltage system (12 V)
- B_c = Battery capacity (1,200 Ah)

C. Analyze Energy Generation versus Load Demand

To obtain more accurate data on the vehicle's energy consumption, load profiles were created. In addition, a power analyzer was installed to record the average daily consumption that might occur during service. The simulation of solar power generation was performed using the System Advisor Model (SAM) software.

Using the solar generation curves and data from the load analyzer, we can visualize the percentage of consumption that the solar photovoltaic system will cover. In photovoltaic systems with battery storage, one of the main challenges is ensuring that the battery bank remains at 100% of its capacity, despite variations in energy consumption by the loads and in the solar system's generation. In many cases, the energy produced by the photovoltaic panels is not sufficient to offset consumption, resulting in an energy deficit that can affect system performance. To address this problem, a calculation method based on an energy balance is proposed that considers the energy available in the battery bank, the energy consumed by the loads, and the energy generated by the photovoltaic system, using data obtained from the solar controller.

Based on this analysis, the remaining energy in the battery is determined, and an assessment is made to determine whether there is a deficit relative to the total capacity. If such a deficit exists, the additional energy that must be supplied by an external battery charger is calculated to ensure that the system operates while maintaining the battery bank at 100% of its capacity. Equation 8 was used to calculate the missing energy capacity:

$$Bc = \frac{E}{V} \quad (8)$$

Where:

- Bc = Energy needed to fully cover the battery bank's capacity [Ah]
- E = Energy supply shortfall [Wh]
- V = Battery Voltage (12V)

The performance of a battery charger is calculated based on fundamental relationships between current, time, and power. First, the required charging time is determined as the ratio of the energy needed to bring the battery bank up to full capacity (in ampere-hours) to the charger's charging current. Next, the power supplied by the charger is calculated as the product of voltage and current (for alternating current). Taking the equipment's efficiency into account, the actual power demand on the input side is adjusted. Finally, the total energy consumed by the charger is obtained by multiplying the required power by the charging time, which allows for an estimate of the energy consumption needed to reach 100% of the battery bank's capacity.

D. Perform Financial Analysis

Now that we have determined the solar system charger's energy consumption, we can calculate the charger's energy cost using a tariff table that lists the cost of energy in L./kWh consumed, depending on the location, in this case, Honduras.

A cost-benefit analysis will be used to determine the profitability of the photovoltaic solar system. The analysis will take into account the investment cost, the energy generated by the solar system, the energy drawn from the national grid, and their unit prices. In addition, the return on investment (ROI) will be analyzed using the Equation 9:

$$ROI = \frac{NetProfit}{InvestmentCost} \times 100 \quad (9)$$

Where:

- ROI = Return on investment [-]
- Net Profit = Average Monthly Net Profit [L]
- Investment Cost = Total initial Project Investment [L]

The annualized ROI was obtained by multiplying the monthly ROI by 12. The profitability ratio was calculated as the average monthly net profit divided by the average

monthly revenue.

III. Results and Discussion

In this section the results and analysis of the research are presented.

A. Nominal Load

The nominal demand for the vehicle was determined. The summary is shown in Table II.

TABLE II
Electrical Load Inventory

Quantity [-]	Equipment [-]	Power [W]	Time of use [h]
1	Dryer	1,800	0.66
1	Vacuum Cleaner	800	0.1
1	Water Pump	192	0.2
2	Hair Clipper	15	0.5
2	Lighting	76	0.83
TOTAL		2,974	2.29

The time shown in Table II refers to the average time per service. To calculate the average daily energy consumption, the number of units by multiplying the power rating of each unit by its operating time. This gave us the energy consumed for a single service, and we took an average of ten services per day to estimate the total energy demand. This value gives us a total of 13.84 kWh per day. This value represents a design assumption rather than a measurement of the actual number of services performed during each monitoring day.

B. Sizing of the system

Radiation data for San Pedro Sula was obtained to calculate the peak sun hours. The minimum solar radiation was 4.116 kWh/m², resulting in a peak sun hours value of 4.116 hours; which means we must assume that we have a minimum solar radiation of 4.116 kWh over 4 hours. The primary objective of sizing a solar photovoltaic system is to ensure that the installation can meet the energy demand of the loads safely, continuously, and in compliance with regulations. According to [8], continuous loads must be considered at 125% of their rated value, in accordance with Articles 210.20(A), 215.3, and 230.42(A), and are defined in Article 100 as those that operate for three hours or more. The inverter was sized based on the maximum simultaneous electrical demand of the equipment, with an additional margin to account for starting and transient loads. Based on the load inventory, an inverter with a nominal capacity of 4 kW was selected to provide sufficient capacity for the connected equipment and expected operating conditions.

Using the rated power of the loads in Table II, the design load was estimated at 3,712 W after applying the applicable continuous-load factor. The installed system uses a Wagan Tech ProLine 10000 inverter rated at 10,000 W continuous output, with a peak capacity of 20,000 W for 10 s. This capacity provides sufficient margin to accommodate the connected loads and their potential starting or transient power requirements.

Due to limited space in the vehicle, only 4.40 m^2 is available; therefore, only a 545 W photovoltaic solar module can be installed. This can be shown in Figure 2.



Fig. 2. Available roof space with the solar module installed

Using the energy obtained in subsection A for nominal demand, the battery capacity was calculated using Equation 3. The battery voltage is 12 V; the number of days of autonomy is set to 1, the maximum battery discharge percentage is 90%, and the thermal compensation factor is 1. This gives us a result of 1,281.92 Ah; however, a 1,200 Ah battery bank was installed based on the available equipment. The battery bank was configured as a 12 V parallel system using deep-cycle GEL batteries. The selected configuration was intended to provide approximately one day of autonomy under the nominal design demand while maintaining the specified maximum depth of discharge. The parallel configuration increases the available ampere-hour capacity while maintaining the 12 V system voltage.

The capacity of the MPPT solar charge controller was determined based on the maximum power generated by the photovoltaic modules and the nominal voltage of the battery bank. In this approach, the required current rating of the controller is obtained by relating the total photovoltaic power to the system voltage. Due to spatial constraints in the mobile van, only one 545 W Solar panel was installed. Considering a 12 V battery system, this configuration results in a required current of approximately 45.41 A, which is conservatively rounded to 46 A for design purposes. Therefore, a charge controller with a minimum capacity of 46 A is required to ensure proper system operation. Additionally, it is necessary to verify that the selected controller meets the open-circuit voltage requirements of the photovoltaic module, which in

MPPT systems typically fall within a range of 100 V to 150 V, ensuring safe and reliable performance under varying operating conditions.

The electrical configuration was selected considering the characteristics of the components and protection devices that were used in the project. The photovoltaic module installed is 545 Wp JA Solar JAM72D30 MB module. It has a nominal open-circuit voltage of 49.75V and short-circuit current of 13.93A. The MPPT charge controller is an AMPINVT AP-80C. This controller supports 12/24/48V battery systems, with the maximum solar input voltage of 150V DC. Thus, according to the installed 545 W module and 12 V battery system, the estimated charging current is about 45.41A. Consequently, the controller capacity is larger than the minimum value required.

The battery bank consists of deep-cycle GEL batteries working at 12V voltage and arranged in parallel configuration. According to the project documentation, the used Sunshine Solar-GEL batteries have nominal capacities of 200 Ah and 300 Ah. The battery bank was designed to work in one day of nominal autonomy with the maximum depth of discharge of 90%. Protection equipment was also provided in the electrical installation, which was dedicated for the photovoltaic circuit, battery circuit, and AC circuit. The given configuration consists of 18 A 750 V DC breaker in the photovoltaic circuit, 350 A DC breaker in the battery circuit, and 250 A DC protection equipment related to the battery/inverter circuit. Wires were chosen considering the estimated current and the requirements of circuits: 6 mm² wire in the photovoltaic circuit, 1/0 AWG wire in the high current battery circuit, and 4 AWG THHN wire in the AC circuit. The choice was done on the basis of nominal equipment capacity.

The study did not include an independent C-rate characterization, detailed battery management system (BMS) specification, vehicle payload verification, or a dedicated thermal-management assessment. These parameters should be evaluated in future work to further validate the long-term safety and reliability of the mobile electrical installation.

The single-line diagram of the system is shown in Figure 3.

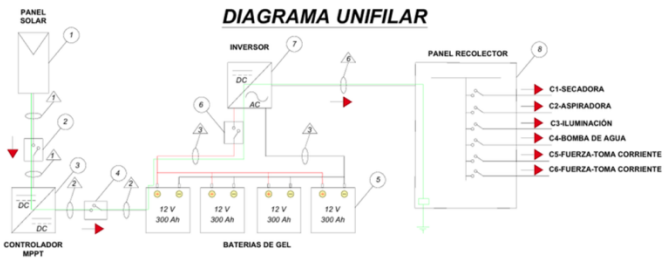


Fig. 3. Single-line diagram

The system is composed of several key components that ensure proper operation and energy management. It begins with a solar panel that captures solar radiation and generates electrical energy, which is protected and regulated through a DC circuit breaker and an MPPT solar charge controller that optimizes energy transfer to the system. The energy is then stored in a battery bank, protected by additional DC breakers to ensure safety and reliability.

The stored energy is converted from direct current to alternating current by an inverter, enabling the operation of electrical loads. Finally, the system distributes power through a main distribution panel, which supplies energy to the different loads connected to the mobile unit

C. Energy generation and demand load

Using the SAM system, the average daily consumption of the solar system is calculated to be 1.07 kWh. Using the net-work analyzer, a power-versus-time graph is obtained, where the area under the curve represents the energy consumed. In turn, the daily generation from the SAM system is plotted. These results are shown in Figure 4.

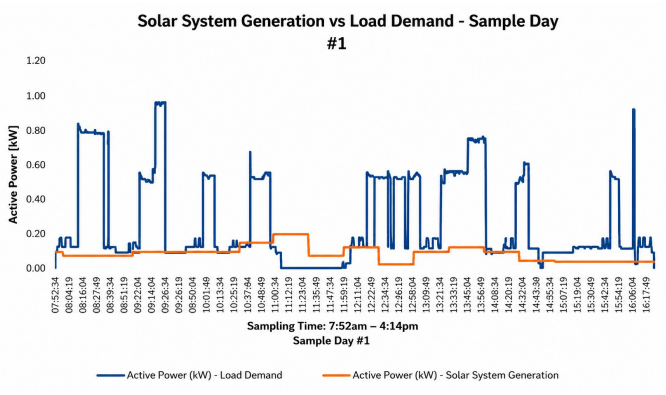


Fig. 4. Graph of Solar System Generation vs. Load Demand—Sample 1

The energy performance of the mobile grooming system was evaluated using measurements collected over ten operating days. Table V summarizes the measured daily electrical demand, photovoltaic generation, and photovoltaic coverage. The measured electrical consumption ranged from 1.525 to 2.848 kWh/day, while photovoltaic generation ranged from 0.512 to 1.874 kWh/day. The average measured demand was 2.279 kWh/day, compared with an average photovoltaic generation of 1.070 kWh/day. The aggregated photovoltaic coverage over the ten-day period was 47.77%. These results indicate that the photovoltaic system provides a substantial contribution to the vehicle's electricity demand but does not independently supply the total energy required for operation. Table III shows the 10-day measurements.

TABLE III
TEN-DAY MEASURED ENERGY PERFORMANCE

Day	Load Demand [kWh]	PV Generation [kWh]	PV Coverage [%]
1	2.220	0.512	23.06
2	2.004	0.603	30.09
3	2.450	1.157	47.22

Day	Load Demand [kWh]	PV Generation [kWh]	PV Coverage [%]
4	2.269	0.950	41.87
5	2.181	0.603	27.65
6	1.525	1.187	77.84
7	1.942	1.330	68.49
8	2.578	1.874	72.69
9	2.768	1.557	56.25
10	2.848	0.926	32.51
Average	**2.279**	**1.070**	**47.77**

The 13.84 kWh/day value represents the nominal design demand, calculated assuming ten grooming services per day. It should therefore be distinguished from the measured operational demand obtained during the ten-day monitoring period. The measured average demand was 2.279 kWh/day and reflects the actual operating conditions recorded during the study period.

The ten-day monitoring dataset included measured electrical load demand and photovoltaic generation, which were used to calculate the photovoltaic contribution shown in Table III. However, grid electricity contribution, battery state of charge (SOC), and system losses were not independently measured or recorded for each operating day. Therefore, these parameters are not reported as daily values in this study. The analysis is limited to the measured load demand, photovoltaic generation, and corresponding photovoltaic coverage. Future measurements should include grid energy consumption, battery SOC, and system losses to provide a complete daily energy balance.

Based on the data obtained, the charging and discharging capacity of the battery bank was calculated. Using Equation 6, we find that the energy drawn from the battery bank is 2.47 kWh, and using Equation 7, the available energy in the battery bank is 14.4 kWh. Therefore, the energy required to fully charge the battery bank is 162.88 Ah, which corresponds to a charging time of 4 hours at a charger current of 40 A. Using this information, the energy consumed by the battery charger was calculated, resulting in 6.32 kWh of energy that must be drawn from the national power grid. Figure 5 shows the final system assembly on the vehicle.



Fig. 5. Final System Assembly

For system sizing purposes, the nominal design demand of 13.84 kWh/day was conservatively used for the battery-bank calculation, while the inverter was sized according to the maximum simultaneous electrical load rather than daily energy consumption. The measured ten-day demand was used to evaluate the actual operational performance of the installed system.

D. Performed Financial Analysis

Taking into account the investment cost, the cost of electricity purchased from the national power grid, the operation and maintenance of the system and the vehicle, and other expenses related to the operation of these activities, the following financial parameters are obtained, as shown in Table IV

TABLE IV
SUMMARY OF FINANCIAL PERFORMANCE INDICATORS

Financial Indicator	Value	Unit
PV System Investment	130,935.00	HNL
Vehicle acquisition	360,000.00	HNL
Total investment	490,935.00	HNL
Average Monthly Revenue	102,857.52	HNL/month
Average Monthly Operating Cost	63,867.06	HNL/month
Average Monthly Net Profit	33,847.58	HNL/month
Average Annual Net Profit	406,170.96	HNL/year
Payback Period	15.0	months
Monthly ROI	6.89	%
Annualized ROI	82.73	%
Profitability Ratio	32.91	%

The financial analysis includes the initial photovoltaic system investment, vehicle acquisition, operating expenses, electricity costs, maintenance expenses, and other costs associated with the operation of the mobile grooming service. The projection is based on the expected service volume and 25 operating days per month. Costs related to financing, depreciation, residual value, and battery replacement were not explicitly modeled in the present analysis and are therefore identified as limitations of the financial assessment.

The financial results indicate that the proposed mobile grooming venture can generate positive operating cash flows under the assumptions considered in the study. The projected payback period of 15 months corresponds to the complete project investment, including the vehicle and photovoltaic system. These results provide an initial techno-economic assessment of the proposed business model; however, the financial performance may vary with changes in service utilization, operating costs, electricity prices, maintenance requirements, and equipment replacement costs.

E. Business Model Innovation Assessment

This section presents an analysis of the business venture and business model for solar-assisted mobile grooming

services. The main points for this evaluation are shown in Table V.

TABLE V
BUSINESS MODEL INNOVATION ASSESSMENT

Assessment Criterion	Conventional Grooming Service	Proposed Mobile Solar-assisted Service
Business location	Fixed commercial facility	Mobile service at the customer's location
Energy source	National electrical grid	Solar photovoltaic system with battery storage
Customer accessibility	Customer must travel to the facility	Door-to-door personalized service
Operating flexibility	Limited to business location	Service available at multiple locations
Operating costs	Higher fixed facility expenses	Reduced infrastructure and electricity costs
Environmental impact	High dependence on grid electricity	Potential reduction in grid electricity consumption through photovoltaic generation
Scalability	Expansion requires new facilities	Fleet expansion through additional mobile units
Business innovation	Traditional service model	Renewable energy integrated with mobile entrepreneurship

To provide a quantitative estimate of the environmental benefit, the photovoltaic contribution was evaluated in terms of electricity generated and potential avoided grid-related emissions. For the illustrative measurement day, the system generated 0.512 kWh of photovoltaic electricity, while the measured load consumption was 2.22 kWh, corresponding to a photovoltaic contribution of approximately 23.06% of the measured daily demand. Using a Honduras grid emission factor of 0.611 kg CO_2/kWh reported in the UNFCCC standardized baseline [9], the photovoltaic generation on this day corresponds to approximately 0.31 kg CO_2 of potentially avoided grid-related emissions. This estimate represents avoided emissions associated with electricity generation and does not include the life-cycle emissions of the photovoltaic modules, batteries, inverter, vehicle, or other equipment. Therefore, the results should be interpreted as a preliminary operational environmental benefit rather than a complete life-cycle environmental assessment.

The comparative analysis shows that the proposed solar-assisted mobile dog grooming service offers several competitive advantages over the conventional business model. Unlike brick-and-mortar dog grooming salons, the proposed solution improves accessibility for customers through in-home service, while reducing dependence on the electrical grid by integrating photovoltaic power generation with battery storage. Furthermore, the mobile business model minimizes infrastructure costs, improves operational flexibility, and facilitates business scalability without the need for additional commercial facilities. These characteristics position the proposed solution as an innovative and sustainable business model that contributes to regional development while promoting the adoption of renewable energy technologies.

The financial assessment is based on the assumptions and operating conditions defined for the proposed business model. A sensitivity analysis of electricity prices, investment costs, utilization levels, and component degradation was not included in the present study. These variables may affect the estimated financial indicators and should therefore be evaluated in future work

IV. CONCLUSIONS

A solar-assisted photovoltaic system with battery storage was designed for a mobile pet grooming vehicle, taking into account the available installation area and the electrical demand of the equipment. The analysis evaluated the relationship between electricity consumption, photovoltaic generation, battery storage, and grid electricity requirements. The main findings of this research are as follows:

- The implementation of a solar photovoltaic system is not entirely feasible as a self-sustaining solution due to the limited space available for installing panels. From a business model perspective, however, the proposal is highly viable, as it improves operational efficiency, reduces costs associated with fixed infrastructure, and expands the coverage of the dog grooming service.
- The system can support the energy needs of the mobile grooming service through a combination of photovoltaic generation, battery storage, and grid electricity.
- The implementation of the system in the mobile van, taking into account both the investment in the solar photovoltaic system and the costs of retrofitting the vehicle, is financially viable. A cash flow analysis that considers the project's revenues and expenses indicates a payback period of approximately 15 months.

This research highlights that renewable energy can serve not only as an alternative power source but also as an enabler of innovative entrepreneurship. The proposed solar-assisted mobile grooming service illustrates how techno-logical innovation and sustainability can be combined to create competitive business models that improve service accessibility, encourage regional economic development, and promote environmentally responsible practices. Consequently, this approach represents a practical pathway for fostering scalable and sustainable enterprises capable of adapting to the evolving demands of the green and digital economy.

V. Limitations and Future Work

Firstly, the energy performance evaluation was based on a ten-day monitoring period and therefore does not capture seasonal variations in solar generation or changes in operating conditions throughout the year. The number of grooming services performed on each monitoring day was not systematically recorded as part of the energy monitoring protocol. Consequently, the measured ten-day demand should be interpreted as an operational sample rather than a seasonal or annual representation of the service. Secondly, although the nominal consumption of 13.84 kWh/day was assumed based on 10 grooming services, it was less than what was measured during the operational performance evaluation.

Similarly, there was no sensitivity analysis performed for the economic analysis of the system under different conditions of electricity price, service utilization, maintenance cost, or battery replacement cost. Finally, a complete life cycle analysis of the photovoltaic system, battery bank, and vehicle has not been performed. The latter will help in estimating degradation, replacement cost, environmental impacts of manufacturing and end-of-life disposal of the components.

Lastly, the market analysis has been done by relying on secondary information. Primary surveys of customers would enhance the findings about customer acceptance, willingness to pay, and demand of the mobile grooming services.

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References

[1] S. E. McDonald, C. Doherty, J. Sweeney, L. Kisiel, A. Matijczak, L. Ni-estat, and M. Gupta, "Barriers to and facilitators of pet grooming among clients served by a subsidized grooming service program," *Frontiers in Veterinary Science*, vol. 9, p. 1021707, Oct. 2022.

[2] J. L. O. Fernandez, J. L. O. Avila, and R. A. Ordo´n˜ez, "Potential effect on the energetic matrix of Honduras with the installation of residential photovoltaic generators for self-consumption," in *2019 IEEE 39th Central America and Panama Convention (CONCAPAN XXXIX)*, (Guatemala City, Guatemala), IEEE, 2019.

[3] H. A. García, A. R. Duke, and H. V. Flores, "Techno-economic comparison between photovoltaic systems with solar trackers and fixed structure in "el Valle de Sula", Honduras," *IOP Conference Series: Earth and Environmental Science*, vol. 776, no. 1, p. 012011, 2021.

[4] Secretaría de Energía, "Actualización del potencial de energía solar térmica en honduras 2023," tech. rep., Secretaría de Energía (SEN), Tegucigalpa, Honduras, Dec. 2023.

[5] American Society for the Prevention of Cruelty to Animals, "Increase access to dog and cat grooming services to improve animal health," 2022. Accessed: Jun. 21, 2026.

[6] Fortune Business Insights, "Mobile pet care market size, share and growth report," 2025. Accessed: Jun. 21, 2026.

[7] Groomit, "On-demand mobile and in-home pet grooming services," 2025. Accessed: Jun. 21, 2026.

[8] National Electrical Code, "Nec 70, 2017," 2017.

[9] United Nations Framework Convention on Climate Change (UNFCCC), *DNA Training on Standardized Baselines*, "Standardized Baselines for Grid Emission Factor in the Caribbean," Honduras, 2020. [Online]. Available: UNFCCC document