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Business Feasibility of Charging Infrastructure to Increase Vehicle Electrification in Indonesia

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Abstract: Progress in developing electric vehicles (EVs) has resulted in substantial advancements in recent years. EVs offer the possibility to effectively reduce carbon emissions while providing vehicle manufacturers with an opportunity to develop a strong presence in emerging markets. Nevertheless, the rapid growth of EVs in Indonesia requires greater expansion. The lack of sufficient facilities to cope with the demand for EVs has led to customer reluctance to adopt this mode of transportation. Also, there is a notable hesitancy among manufacturers and business professionals to engage in the production of EVs and the establishment of charging infrastructure. This hesitation arises primarily from the lack of apparent market demand, which may be attributed to the significant investment costs connected with these ventures. This study, therefore, aims to develop an Annual Cost of the System (ACS) cost model to assess and select potential economically feasible and operationally feasible investments for the provision of Public Electric Vehicle Charging Stations (SPKLU) and Public Electric Vehicle Battery Exchange Stations (SPBKLU) services in Indonesia. When creating investment decisions, it is necessary to take into consideration a range of feasibility analysis variables, including but not limited to Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP). Moreover, this study additionally performed a sensitivity analysis to determine actionable recommendations for persons within the business community.

Keywords: Electric vehicle infrastructure, electric vehicles, annual cost of the system, business feasibility analysis.

Introduction

Presently, there has been a growing recognition within the government regarding the significance of mitigating carbon emissions from the transportation sector as a crucial objective in averting the adverse impacts of the greenhouse effect and global warming [1]. Furthermore, there is a growing awareness within the automotive manufacturing sector and among consumers regarding the advantages and needs of developing and utilizing products and services with reduced carbon emissions. The transportation industry is now also undergoing a transition from conventional fossil fuels to alternative energy sources that are more environmentally sustainable. This movement is driven by the recognition that the transportation sector is the primary source of carbon gas emissions, thus necessitating a move towards greener alternatives [2]. In this case, Indonesia is a nation where individuals are heavily reliant on motorized vehicles in their daily activities. The rise in the number of motorized vehicle users in Indonesia proves that motorized cars are increasingly being seen as a necessity within the community.

Nowadays, there is also a growing trend towards the utilization of electrical energy as the primary driving force for conventional motorized vehicles. The Indonesian Government has implemented many policies to facilitate the adoption of electric vehicles (EVs) throughout the country. One example is Presidential Regulation Number 55 of 2019, which ensures the expeditious implementation of the Battery Electric Vehicle Program for Road Transportation. This rule aims to implement a policy that expedites the development program for electric motorized vehicles in Indonesia. The regulation also governs the organization of preliminary phases in facilitating the presence of EVs, encompassing the establishment of refueling infrastructure and determining energy pricing. Furthermore, this regulation of EV advancement establishes policies pertaining to research, development, and innovation within the battery-powered automotive sector [3]. In Indonesia, the decision to purchase EVs, especially electric motorcycles, are mostly impacted by the knowledge possessed by potential consumers [4]. In the forthcoming years, the demand for electricity is anticipated to persistently rise in tandem with the growth and advancement of the population, investment levels, and technical progress, including the evolution of the transportation industry.

EVs also present a promising prospect for mitigating carbon emissions and offer vehicle manufacturers an alternate avenue to establish dominance in emerging countries. Nevertheless, the adoption of EVs in Indonesia needs further expansion. The limited availability of infrastructure supporting electric driving poses a significant barrier for consumers, leading to their hesitancy in purchasing EVs. However, manufacturers and business professionals exhibit reluctance in the production of EVs and the establishment of charging infrastructure due to the absence of evident market demand, mostly due to the substantial investment costs associated with these endeavors. These two parameters are highly correlated. The production of EVs relies heavily on the presence of charging infrastructure. Insufficient availability of charging stations in relation to the high production of EVs can result in a surplus demand for power. Conversely, if the manufacture of EVs is limited, there will be an excess of power supply. Hence, it is imperative to establish a favorable infrastructural environment that might stimulate the widespread adoption of EVs.

The establishment of charging infrastructure for Battery-based Electric Motorized Vehicles (KBLBB) is a crucial element in the endeavor to expand the electric car market in Indonesia. The expeditious development of the electrification transition in Indonesia's transportation sector can be facilitated by the provision of sufficient EV charging infrastructure. Furthermore, governmental support is crucial for the advancement of transportation electrification [5]. This support can manifest in the implementation of legislation pertaining to the establishment of public charging infrastructure. In Indonesia, there are two different types of battery charging infrastructure accessible: SPKLU utilizing the Conductive Charging method and SPBKLU implementing the Battery Swapping method. These options are in accordance with the guidelines outlined in the Regulation of the Minister of Energy and Mineral Resources No. 1 of 2023, which pertains to the establishment of electric charging infrastructure for battery-powered electric motorized vehicles [6]. The conductive charging method refers to a technique wherein the charger is directly connected to the vehicle, establishing physical contact between the power source and the battery through a connector [7]. The battery-swapping method is a highly efficient and convenient charging technique. It involves the straightforward process of replacing depleted batteries with fully charged ones, hence eliminating the need for consumers to put up with lengthy waiting periods [8]. In the context of Indonesia, it is worth noting that the SPKLU is exclusively accessible for electric automobile vehicles, while the SPBKLU is specifically designated for electric motorbikes. According to data provided by the state electricity company (PLN) and Research Director Foundry, there were 846 SPKLU units and.700 SPBKLU units in Indonesia as of September 2023 [9], [10]. In comparison, the number of EV users in Indonesia was around 81.525 units as of September 2023, with details of 62.815 electric motorbikes, 320 electric three-wheeled vehicles, 18.300 electric cars, 80 electric buses, and 10 electric freight cars [11].

When considering the development of charging infrastructure, it is crucial to consider numerous variables, such as the type of charging station, the associated investment costs, and the optimal location of the charging infrastructure [12]. The determination of the investment cost associated with the establishment of a charging infrastructure may be accomplished through the utilization of diverse cost models, among which the ACS cost model stands as one viable solution. The ACS is a widely utilized cost model that serves to quantify and assess all expenses associated with the assembly and integration of a given system. The model utilized in the study titled *"Reliability and economic evaluation of a microgrid power system"* was developed specifically for microgrid systems [13]. A few prior investigations have been conducted on the topic of cost estimation utilizing the ACS cost model. Specifically, Balashov [14] examined the cost calculation for charging stations incorporating photovoltaic systems, while Singh *et al.* [15] focused on hybrid electric systems. Frequently, the ACS cost model is employed in the computation of investment expenses for charging stations integrated with microgrids or hybrid electric systems, as evidenced by prior research.

Nevertheless, the utilization of the ACS cost model is hardly observed in scenarios involving grid-based electrical systems. Thus, this study is focused on developing a cost model, known as the Annual Cost of the System (ACS), to compare the investment costs associated with establishing KBLBB charging infrastructure in Indonesia. The objective is to identify the most suitable and viable investment option for implementation. The aim is for business professionals to utilize the conclusions of this research to facilitate the implementation of the KBLBB program by installing a charging station. The limitation and weakness of this research is that the scope of research was primarily only in the Central Java and Yogyakarta regions. Further, the consideration of the ACS model is anticipated to speed up car electrification and facilitate the proliferation of charging infrastructure inside Indonesia.

Methods

Conceptual Framework Design

The conceptual framework comprises several key components, including an explanation of the EV infrastructure charging business model, identification of alternatives of charging infrastructure business investments, establishment of the overarching structure of the ACS cost model, and formulation of the ACS cost model itself.

EV Infrastructure Charging Business Model

Nowadays, three distinct types of technology exist within the realm of charging infrastructure. These include conductive charging technology, inductive charging technology, and charging technology that utilizes battery switching [7]. Nevertheless, out of the three technology categories, it is noteworthy that the Indonesian Government has solely implemented regulations on two of them: conductive charging technology and charging technology involving battery swapping. The conductive charging method refers to a battery charging technology that establishes a direct connection between the connector on an EV and the power supply. According to Martínez-Lao *et al.* [16], there are three distinct categories based on the speed at which charging occurs: Slow Charging, Fast Charging, and Rapid Charging.

The Slow Charging method utilizes a standard single-phase 230 V AC outlet with a maximum current capacity of 16 A. The process of fully charging an electric car typically requires a time frame of 6 to 8 hours. In contrast, an electric motorbike necessitates a complete recharge within a time frame of 2 to 3 hours. Fast charging utilizes either a single-phase or three-phase alternating current (AC) outlet, capable of delivering a maximum current of 63A. The process of charging an EV typically requires a duration ranging from 1 to 2 hours. However, electric motorbikes are unable to endure this method of recharging. The process of Rapid Charging involves the use of direct current (DC) with a voltage range of 50 to 500 volts and an amperage range of 50 to 550 amps. The process of fully charging an electric car typically ranges from 5 to 30 minutes. Moreover, according to Sarker *et al.* [8], the battery swapping method is regarded as the most efficient and convenient charging approach due to its ability to replace depleted batteries with fully charged ones promptly. This method offers a convenient solution for consumers, eliminating the need for extended waiting periods. This approach is sometimes referred to as Battery Exchange.

Regulation of the Minister of Energy and Mineral Resources No. 1 of 2023 has been implemented to govern the SPKLU business model in Indonesia. Nevertheless, the selling of electricity has been subject to regulation by PLN, resulting in modifications to the business structure outlined in Table 1. Meanwhile, the SPBKLU business model applied to lease batteries can take the following structure: 1) SPBKLU business actors provide batteries for rent to the owner of a battery-electric vehicle and have a battery swapping cabinet (battery provider, cabinet owner — BPCO) and 2) SPBKLU business actors provide batteries for lease to battery-electric vehicle owners and rent battery swapping cabinets from partners (battery provider, cabinet lease - BPCL).

Table 1. Adjustment of business model

Business Model	Description			
	Electricity Provider	EV Charger Equipment Investment	Land	Operation & Maintenance
Model 1	PLN	Private	Private	Private
Model 2	PLN	Private	PLN	Private
Model 3	PLN	Private	-	Private

Alternatives of Charging Infrastructure Business Investments

The determination of the number of alternatives for SPKLU can be obtained by multiplying the number of location clusters, the number of adjustment business models, and the number of type land, resulting in a total of 42 options. PLN, the primary supplier and distributor of electrical energy in Indonesia, has provided three packages for SPKLU. Table 2 presents the charging machine package for SPKLU. Based on the Regulation of the Minister of Energy and Mineral Resources No 1 of 2023, there are seven location clusters for constructing SPLKU outlined in Table 3. The result of 42 options for SPKLU is outlined in Table 4. The determination of the number of alternatives for SPBKLU is based on the data of available exchange stations that have been circulating within the Indonesian context, resulting in a total of two options outlined in Table 5.

Table 2. Charging machine package of SPKLU

Package	Power	Land	Price
Medium charging	25 kW	Outdoor	IDR 352,940,000
		Indoor	IDR 342,180,000
Fast charging	50 kW	Outdoor	IDR 566,060,000
		Indoor	IDR 555,300,000
Ultra-fast charging	100 kW	Outdoor	IDR 1,053,350,000
		Indoor	IDR 1,042,590,000

Table 3. Location clusters

Location Clusters	Minimum Requirements
Settlement	At least one unit of medium charging
Office	At least one unit of medium charging
Mall	At least one unit of medium charging
Arterial Road	At least one unit fast charging
Highway Rest Areas	At least one unit fast charging
Gas Station (SPBU)	At least one unit fast charging
Parking Lot	At least one unit of medium charging

Table 4. Alternatives of SPKLU

Option	Location Clusters	Minimum Requirements	Land	Business Model
1	Settlement	At least one unit of medium charging	Outdoor	Model 1
2	Settlement	At least one unit of medium charging	Outdoor	Model 2
3	Settlement	At least one unit of medium charging	Outdoor	Model 3
4	Settlement	At least one unit of medium charging	Indoor	Model 1
5	Settlement	At least one unit of medium charging	Indoor	Model 2
6	Settlement	At least one unit of medium charging	Indoor	Model 3
7	Office	At least one unit of medium charging	Outdoor	Model 1
8	Office	At least one unit of medium charging	Outdoor	Model 2
9	Office	At least one unit of medium charging	Outdoor	Model 3
10	Office	At least one unit of medium charging	Indoor	Model 1
11	Office	At least one unit of medium charging	Indoor	Model 2
12	Office	At least one unit of medium charging	Indoor	Model 3
13	Mall	At least one unit of medium charging	Outdoor	Model 1
14	Mall	At least one unit of medium charging	Outdoor	Model 2
15	Mall	At least one unit of medium charging	Outdoor	Model 3
16	Mall	At least one unit of medium charging	Indoor	Model 1
17	Mall	At least one unit of medium charging	Indoor	Model 2
18	Mall	At least one unit of medium charging	Indoor	Model 3
19	Arterial Road	At least one unit fast charging	Outdoor	Model 1
20	Arterial Road	At least one unit fast charging	Outdoor	Model 2
21	Arterial Road	At least one unit fast charging	Outdoor	Model 3
22	Arterial Road	At least one unit fast charging	Indoor	Model 1
23	Arterial Road	At least one unit fast charging	Indoor	Model 2
24	Arterial Road	At least one unit fast charging	Indoor	Model 3
25	Highway Rest Areas	At least one unit fast charging	Outdoor	Model 1
26	Highway Rest Areas	At least one unit fast charging	Outdoor	Model 2
27	Highway Rest Areas	At least one unit fast charging	Outdoor	Model 3
28	Highway Rest Areas	At least one unit fast charging	Indoor	Model 1
29	Highway Rest Areas	At least one unit fast charging	Indoor	Model 2
30	Highway Rest Areas	At least one unit fast charging	Indoor	Model 3
31	Gas Station (SPBU)	At least one unit fast charging	Outdoor	Model 1
32	Gas Station (SPBU)	At least one unit fast charging	Outdoor	Model 2
33	Gas Station (SPBU)	At least one unit fast charging	Outdoor	Model 3
34	Gas Station (SPBU)	At least one unit fast charging	Indoor	Model 1
35	Gas Station (SPBU)	At least one unit fast charging	Indoor	Model 2
36	Gas Station (SPBU)	At least one unit fast charging	Indoor	Model 3
37	Parking Lot	At least one unit of medium charging	Outdoor	Model 1
38	Parking Lot	At least one unit of medium charging	Outdoor	Model 2
39	Parking Lot	At least one unit of medium charging	Outdoor	Model 3
40	Parking Lot	At least one unit of medium charging	Indoor	Model 1
41	Parking Lot	At least one unit of medium charging	Indoor	Model 2
42	Parking Lot	At least one unit of medium charging	Indoor	Model 3

Table 5. Alternatives SPBKLU

Option	Swap Battery Box	Price
1	3 Compartment Swap Battery Box	IDR 18,000,000
2	8 Compartment Swap Battery Box	IDR 150,000,000

The Establishment and Formulation of the ACS Cost Model

The determination of the general structure of the ACS cost model refers to the cost model by Adefarati *et al.* [13] as described in Equation 1. Table 6 presents the components of the development model taken from the operational variable ACS cost model.

$$ACS = AMC + AFC + AEC + ACC + ARC \quad (1)$$

Notation:
AMC = Annualized Operation & Maintenance Cost ($/Year)
AFC = Annualized Fuel Cost ($/Year)
AEC = Annualized Emission Cost ($/Year)
ACC = Annualized Capital Cost ($/Year)
ARC = Annualized Replacement Cost ($/Year)

Table 6. Operational variable ACS cost model

Component	Variable	Reference	Attribute	Unit	Minimum Requirements
ACS Outflow	Annualized Operation & Maintenance Cost (AMC)	[17], [18]	Maintenance Cost	IDR/Year	The cost of maintaining the charging infrastructure system incurred
		[19]	Monitoring Cost	IDR/Year	The cost of monitoring the charging infrastructure machine incurred
	Annualized Capital Cost (ACC)	[19]	Equipment Cost	IDR/Year	The amount of costs incurred for the purchase of equipment
		[20]	Land Cost	IDR/Year	The cost of renting land for infrastructure development
	Annualized Electricity Cost (AEC)	[13]	Fuel Cost	IDR/Year	The amount of electricity costs incurred for charging infrastructure needs for a year
	Annualized Replacement Cost (ARC)	[21]	Replacement Cost	IDR/Year	The cost of component replacement
ACS Inflow	Annualized Energy Production Cost (AEPC)	[13]	Energy Production (EP)	kWh/Year	The amount of total energy used by users per kWh to charge EVs for a year
		[13]	Cost of Energy (COE)	IDR/kWh	The amount of electricity costs that must be paid by users per kWh to charge EVs

This ACS model was developed from the Adefarati [13] and Daniel *et al.* [19] models. This ACS model shows the difference between the ACS outflow and ACS inflow values. While the ACS outflow model represents the overall expenses associated with the investment and operation of the annual charging infrastructure, the ACS inflow model represents the overall revenue generated from the annual operations of charging infrastructure. The disparity between the outflow and inflow values is utilized to ascertain the amount of profit that will be acquired. The development of the ACS model can be approached with a formula described in Equation 2.

$$ACS = ACS_{OUTFLOW} - ACS_{INFLOW} \quad (2)$$

Notation:
$ACS_{OUTFLOW}$ = Annual Cost of the System Outflow (IDR/Year)
ACS_{INFLOW} = Annual Cost of the System Inflow (IDR/Year)

The ACS Outflow model consists of the sum of AMC, ACC, AEC, and ARC described in Equation 3.

$$ACS_{OUTFLOW} = \left(C_{eqp} + AMC + ACC + AEC + ARC\right) \quad (3)$$

Notation:
AMC = Annualized Operation & Maintenance Cost (IDR/Year)
ACC = Annualized Capital Cost (IDR/Year)
AFC = Annualized Electricity Cost (IDR/Year)
ARC = Annualized Replacement Cost (IDR/Year)
C_{eqp} = The cost of purchasing a charging machine in the first year (IDR)

The AMC formula is described in Equation 4.

$$AMC = \sum_{i=1}^{n} C_{maint_n} + C_{mon_n} \tag{4}$$

Notation:
C_{main_n} = Maintenance costs incurred in a year (IDR/Year)
C_{mon_n} = Monitoring costs incurred in a year (IDR/Year)

ACC formula is described in Equation 5.

$$ACC = \sum_{i=1}^{n} C_{land_n} \tag{5}$$

Notation:
C_{land_n} = Land rental costs incurred in a year (IDR/Year)

The AEC formula is described in Equation 6.

$$AEC = EP \times \sum_{i=1}^{n} C_{fuel_n} \tag{6}$$

Notation:
EP = Energy Production (kWh/Year)
C_{fuel_n} = Electricity cost in a year (IDR/Year)

ARC formula is described in Equation 7.

$$ARC = \sum_{i=1}^{n} C_{rep_n} \tag{7}$$

Notation:
C_{rep_n} = Replacement component in a year (IDR/Year)

The ACS Inflow model consists of the multiply of COE and EP described in Equation 8.

$$ACS_{INFLOW} = AEPC = \sum_{i=1}^{n} COE_n \times EP_n \tag{8}$$

Notation:
$AEPC$ = Annualized Energy Production Cost (IDR/Year)
COE_n = Cost of Energy (IDR/kWh)
EP_n = Energy Production (kWh/Year)

Results and Discussion

Calculations of SPKLU

AMC calculation is the sum of maintenance costs and monitoring costs. The maintenance cost associated with a charging station amounts to 1% of the initial capital investment [22], [23]. The annual monitoring cost for the charging station amounts to $500 or IDR 7,500,000, assuming a USD to IDR exchange rate of 15,000 [19]. It is postulated that the AMC has seen a consistent growth pattern, with increments occurring every five years, corresponding to the average inflation rate of 3.09%, throughout six years from 2017 to 2022. Then, the ACC calculation is the sum of initial machine purchase costs and land rental costs. The minimum land that must be provided by business actors is 42 m^2. It is assumed that the charging machine has an economic life of 10 years with a market value of 10% [19]. In addition, AEC consists of fuel costs, which are regulated in the Regulation of the Minister of Energy and Mineral Resources No 28 of 2016, namely bulk tariffs (C/TM) with the formula Q ($0.8 < Q \leq 2$) multiplied IDR 707 [24]. The PT PLN Board of Directors determines the multiplier factor, Q, which is used to differentiate between commercial users and non-commercial consumers. Besides, ARC comprises replacement costs, where the charging infrastructure machine is commonly believed to have a technical lifespan of 20 years. The machine will undergo replacement upon the conclusion of the project duration, resulting in a value of IDR 0. The selling price of electricity has been subject to regulation under the Regulation of the Minister of Energy and Mineral Resources No 1 of 2023, with a fixed rate of IDR 2,475 per kilowatt-hour (kWh) for all charging technologies. However, the opportunity cost was not considered in the calculations. The process of identifying investment options for providing SPKLU involved the integration of 7 area clusters, 3 adjustment business models, and 2 criteria for selecting suitable land for charging stations. The number of options was determined by multiplying the number of area clusters, the number of adjustment business models, and the number of land areas, resulting in a total of 42 options. The result of the ACS calculation for SPKLU is illustrated in Figure 1.

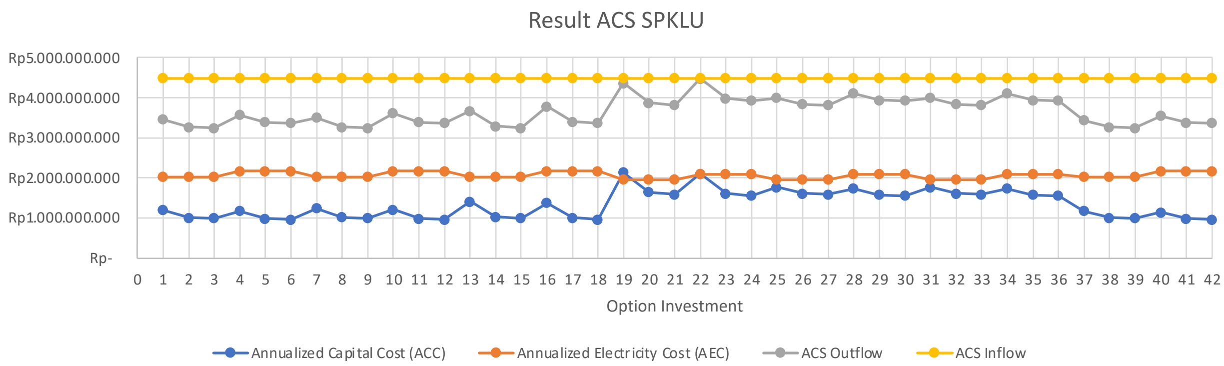

Figure 1. Result of ACS SPKLU

Calculations of SPBKLU

The total maintenance and monitoring costs are the AMC calculation. One percent of the initial capital investment is allocated to maintenance costs for charging stations [22], [23]. At a USD to IDR exchange rate of 15,000, the charging station's yearly monitoring cost comes to $500, or 7,500,000 IDR [19]. The AMC is assumed to have exhibited a stable growth pattern during the six years from 2017 to 2022, with increases taking place every five years or in line with the average inflation rate of 3.09%. Besides, ACC calculation is the sum of initial machine purchase costs and land rental costs. When establishing SPBKLU, it is not required to provide land; nonetheless, the provision of spare batteries is required. It is assumed that the charging machine has an economic life of 10 years with a market value of 10% [19]. The next component of AEC is fuel costs, which are governed by the Minister of Energy and Mineral Resources Regulation No. 28 of 2016. Specifically, bulk tariffs (C/TM) are calculated using the formula Q ($0.8 < Q \leq 2$) multiplied by IDR 707, yielding a value of IDR 1,198.45 [24]. The multiplier factor, Q, which is used to distinguish between commercial and non-commercial customers, is set by the PT PLN Board of Directors. SPBKLU is believed to have a continuous operation of 24 hours, and the battery will reach maximum capacity after being charged for 4 hours. The battery at SPBKLU has special specs, specifically 72V 20Ah, resulting in a power output of 1.44 kWh per battery. In addition, it is presumed that the batteries at SPBKLU are capable of satisfying the demand, such that all the batteries are hired out in a single day. Based on this assumption, it can be estimated that the number of batteries rented out in a year would be 6.570 units for option 1 and 17.520 units for option 2. Moreover, ARC encompasses replacement costs, as the charging infrastructure machine is generally thought to have a 20-year technical lifespan. By the time the project is over, the machine will be replaced, and its worth will be IDR 0. The rental charge per battery is deemed to be IDR 10,000 [25]. Nevertheless, opportunity cost is not taken into account in the calculation. The result of the ACS calculation for SPBKLU is presented in Table 7.

Table 7. Result ACS SPBKLU

Option	Annualized Capital Cost (ACC)	Annualized Electricity Cost (AEC)	ACS Outflow	ACS Inflow
1	IDR 98,000,000	IDR 75,588,638	IDR 339,023,493	IDR 438,000,000
2	IDR 586,600,000	IDR 201,569,702	IDR 953,604,557	IDR 1,168,000,000

Analysis of Investment Feasibility

The assessment of investment feasibility encompasses the computation of key financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP) for each available option. The most beneficial choice is chosen through the process of establishing the criteria for selection. The eligibility criteria for selection include a positive Net Present Value (NPV), an Internal Rate of Return (IRR) greater than the Minimum Acceptable Rate of Return (MARR), and the shortest Payback Period (PBP). The positive Net Present Value (NPV) criterion holds significant importance as it enables business individuals to prioritize the attainment of favorable benefits. The magnitude of profit increases in direct proportion to the positivity and magnitude of the value. The MARR value is presumed to be 5.75% based on the interest rate set by Bank Indonesia on July 24-25, 2023. The NPV value for each SPKLU option is depicted in Figure 3. The NPV value for each SPBKLU option is shown in Table 8.

Table 8. NPV value SPBKLU

Option	NPV Value
1	IDR 26,338,145
2	- IDR 34,123,377

Hence, the most optimal alternatives for the supply of SPKLU are options 15 and 39. These options exhibit positive Net Present Value (NPV) values, Internal Rate of Return (IRR) values that surpass the Minimum Acceptable Rate of Return (MARR), and the shortest Payback Period (PBP) values. Option 15 is an alternative to provide SPKLU in clusters of mall locations with medium charging technology and outdoor areas and a business model adjustment model 3. Option 39 is an alternative to provide SPKLU in clusters of parking lots with medium charging technology and outdoor areas and a business model adjustment model 3.

Meanwhile, the most optimal alternatives for the supply of SPBKLU are option 1. This option exhibits positive Net Present Value (NPV) values, Internal Rate of Return (IRR) values that surpass the Minimum Acceptable Rate of Return (MARR), and the shortest Payback Period (PBP) values. Option 1 is an alternative to provide SPBKLU with SGB machines, 3 Swap Battery Storage Boxes, and 2 spare swap batteries.

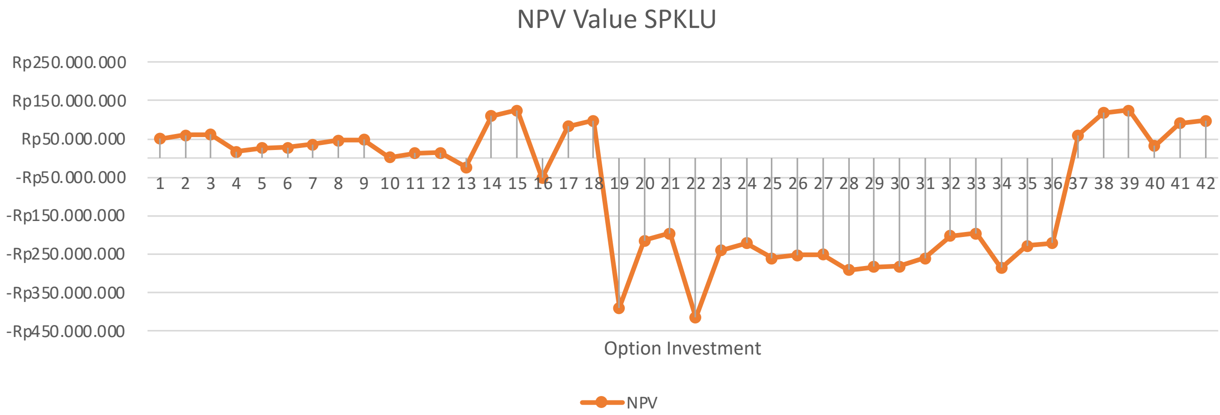

Figure 2. NPV value SPKLU

Sensitivity Analysis

A sensitivity analysis was conducted by implementing three distinct sensitivity test scenarios on the most beneficial choices for delivering SPKLU and SPBKLU, respectively. The purpose was to ascertain the impact of various variable modifications on the Net Present Value (NPV) value. The variables that would undergo fluctuations include electricity rates, bank interest rates (MARR), electricity selling prices, and battery rental pricing. The variables to be calculated in the SPKLU scenario are electricity selling prices, electricity rates, and MARR. Meanwhile, the variables to be calculated in the SPBKLU scenario are battery rental pricing, electricity rates, and MARR. Tables 9 and 10 present the spider plot table for sensitivity analysis for SPKLU and SPBKLU, respectively.

Table 9. Table of spider plot for SPKLU

% Change	Electricity Selling Prices	Electricity Rates	MARR (%)
-100%	-IDR 1,667,143,673	IDR 1,282,647,222	IDR 806,019,215
-75%	-IDR 1,159,770,879	IDR 1,052,572,293	IDR 662,171,799
-50%	-IDR 652,398,084	IDR 822,497,363	IDR 543,537,115
-25%	-IDR 145,025,290	IDR 592,422,434	IDR 444,931,085
0%	IDR 362,347,504	IDR 362,347,504	IDR 362,347,504
25%	IDR 869,720,299	IDR 132,272,575	IDR 292,670,306
50%	IDR 1,377,093,093	-IDR 97,802,355	IDR 233,460,254
75%	IDR 1,884,465,888	-IDR 327,877,284	IDR 182,795,883
100%	IDR 2,391,838,682	-IDR 557,952,213	IDR 139,154,174

The impact of altering the value of a variable on the net present value (NPV) for SPKLU can be observed in Figure 3. Both the electricity rate variable and the bank interest rate variable (MARR) exhibit a similar association with the Net Present Value (NPV), resulting in a negative value. An escalation in electricity rates or interest rates (MARR) would result in a decrease in the Net Present Value (NPV) that is anticipated to be obtained. Nevertheless, a decrease in the electricity rate would result in an augmented Net Present Value (NPV) that will be acquired. In contrast, there exists a positive correlation between the variable representing the selling price of consumer electricity and the Net Present Value (NPV). An upward adjustment in the selling price of consumer electricity will result in a corresponding rise in the Net Present Value (NPV) received, while a decrease in the selling price will lead to a decrease in the NPV value, and vice versa.

Table 10. Table of spider plot for SPBKLU

% Change	Battery Rental Pricing	Electricity Rates	MARR (%)
-100%	-IDR 172,377,016	IDR 60,804,102	IDR 62,995,916
-75%	-IDR 122,698,226	IDR 52,187,612	IDR 51,157,386
-50%	-IDR 73,019,436	IDR 43,571,123	IDR 41,363,635
-25%	-IDR 23,340,645	IDR 34,954,634	IDR 33,198,067
0%	IDR 26,338,145	IDR 26,338,145	IDR 26,338,145
25%	IDR 76,016,935	IDR 17,721,656	IDR 20,532,523
50%	IDR 125,695,726	IDR 9,105,167	IDR 15,584,067
75%	IDR 175,374,516	IDR 488,678	IDR 11,337,180
100%	IDR 225,053,307	-IDR 8,127,811	IDR 7,668,282

Furthermore, the slope of the line depicted in Figure 3 exhibits the highest degree of sensitivity in the Net Present Value (NPV) when there is a modification in the selling price of consumer electricity. According to the data presented in Figure 3, when the variable representing the selling price of consumer electricity is decreased by 25%, the resulting Net Present Value (NPV) is negative. This indicates that the project is not economically viable and would result in a financial loss. In the event that the variable representing the electricity rate experiences a 50% increase, the resulting negative Net Present Value (NPV) denotes that the project is not economically viable and would result in a loss.

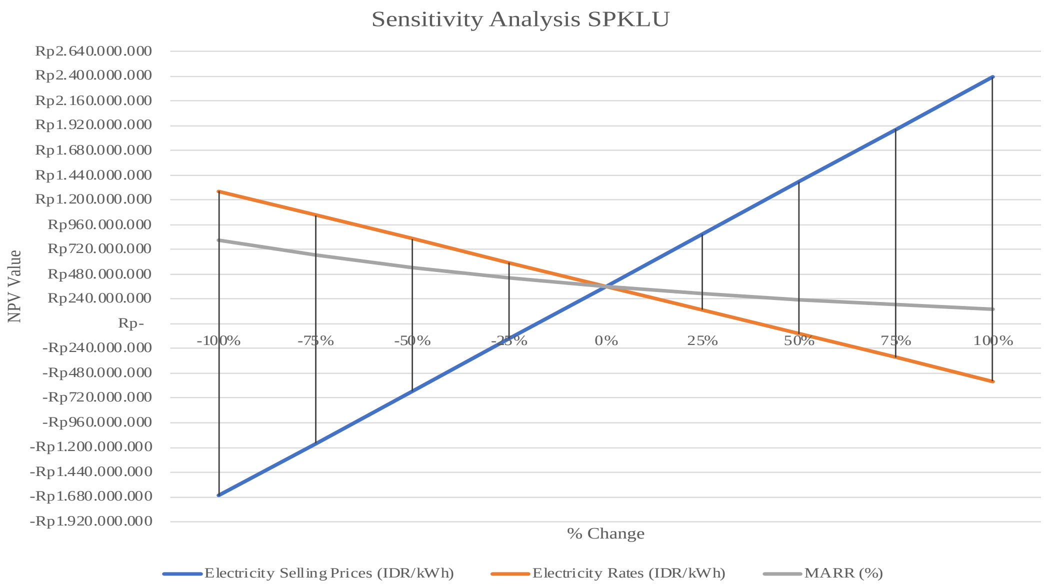

Figure 3. Sensitivity analysis for SPKLU

Figure 4 illustrates how changing a variable's value affects SPBKLU's net present value (NPV). The relationship between the electricity rate variable, the bank interest rate variable (MARR), and the Net Present Number (NPV) is similar and results in a negative value. There would be a reduction in the expected Net Present Value (NPV) if interest rates or electricity rates (MARR) increased. However, if the electricity rate drops, an increased net present value (NPV) will be obtained. On the other hand, there is a positive link between the Net Present Value (NPV) and the variable of the battery rental price. When the battery rental price is adjusted upward, the Net Present Value (NPV) received will also increase; conversely, when the battery rental price is adjusted downward, the NPV value will fall.

Moreover, it is clear that when the battery rental price is altered, the Net Present Value (NPV) is most sensitive along the slope of the line shown in Figure 4. Based on the information illustrated in Figure 4, a 25% reduction in the variable that represents the battery rental price results in a negative Net Present Value (NPV). This suggests that there would be a financial loss and that the project is not economically feasible. Should the variable denoting the electricity tariff rise by 100%, the consequent negative Net Present Value (NPV) suggests that the project is not financially feasible and would incur a loss.

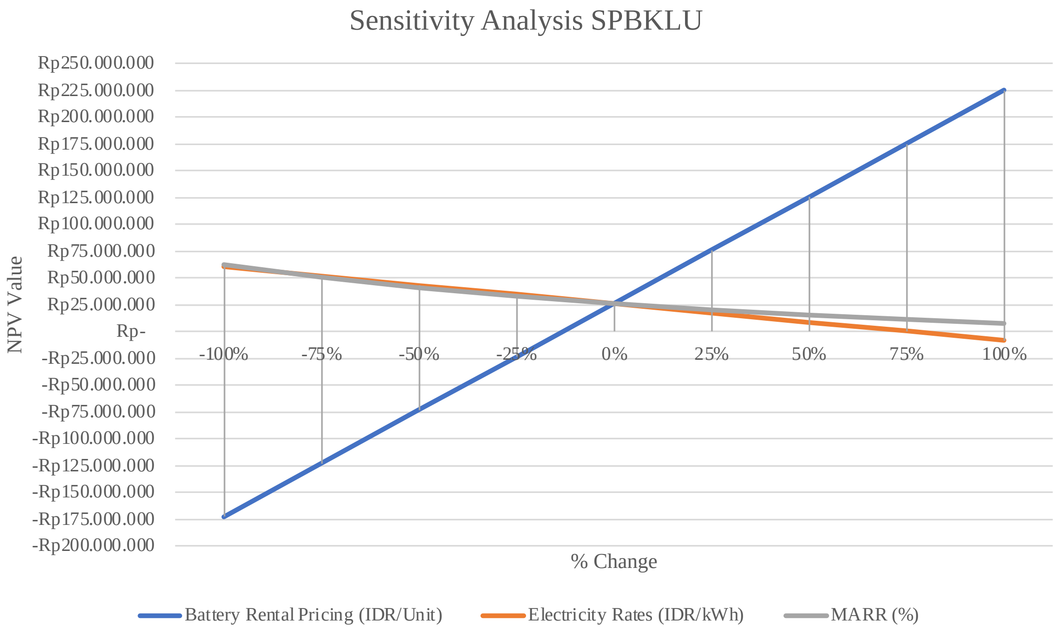

Figure 4. Sensitivity Analysis for SPBKLU

The government can implement a specific power tariff policy for enterprises, encompassing both SPKLU and SPBKLU charging infrastructure. The previous scenario involving fluctuations in electricity pricing is among the circumstances that enhance the case for the widespread implementation of EVs in China[26], [27]. This scenario is implemented by the reduction of electricity rates. The decrease in electricity tariffs has a notable impact on the expenditure associated with acquiring electricity. The purchasing expenditure associated with energy has witnessed a drop due to the fall in electricity tariffs. As a result, a decrease in electricity tariffs will result in a reduction in the financial burden of purchasing electricity for businesses.

In addition to implementing a specialized electricity tariff policy, the government can formulate policies pertaining to alterations in the selling price of energy at SPKLU for consumers, as well as the rental price for swapping batteries at SPBKLU. One potential regulatory approach involves implementing pricing limitations on businesses based on the charging technology they employ. Presently, the selling price of electricity to customers remains fixed at IDR 2.475 per kWh, regardless of the specific charging technology employed. This scenario is derived from a study conducted by Yang *et al.* [28]. By modifying the selling price of energy to consumers, specifically by decreasing it by 20% and increasing it by 20%, it becomes evident that a positive correlation exists between the quantity of electricity supplied and the corresponding sales volume.

Consequently, this relationship leads to larger profits. The determination of the interest rate change scenario, also known as the Minimum Acceptable Rate of Return (MARR), is predicated upon empirical findings from Cunha *et al.*'s [29] research, which suggests that the economic feasibility of this project is contingent upon a low MARR value. There exists a strong correlation between fluctuations in interest rates, specifically the Minimum Acceptable Rate of Return (MARR), and changes in the overall level of inflation. Hence, it is anticipated that the government will endeavor to uphold the stability of the Indonesian economy through the augmentation of employment opportunities, thereby mitigating the unemployment rate in Indonesia. Additionally, the implementation of prudent monetary policies and the formulation of fiscal policies pertaining to government spending and expenditures are also anticipated.

Conclusions

The purpose of this study was to create an ACS cost model to assess the viability of different investment options. The aim is for business professionals to utilize the conclusions of this research to facilitate the implementation of the KBLBB program by installing a charging station. The consideration of the ACS model is anticipated to expedite the process of car electrification and facilitate the proliferation of charging infrastructure inside Indonesia. The ACS cost model that has been created encompasses the disparity between the outflow and inflow values of ACS. The ACS outflow covers the aggregate of yearly expenses related to operations and repairs (AMC), capital investments (ACC), power consumption (AEC), and component replacements (ARC). The AMC combines the aggregate expenses associated with maintenance and monitoring on an annual basis. The ACC variable covers the aggregate expenditure associated with the acquisition of the machinery as well as the annual rental expenses for the land. The AEC provides an annual assessment of the overall expenses associated with energy rates. In addition, the Annual Replacement Cost (ARC) encompasses the comprehensive expenditure associated with the replacement of components within a given year. In the context of ACS inflow, the term encompasses the aggregate revenue generated from the annual operations of charging infrastructure. Specifically, it refers to the overall cost of energy production per annum, commonly known as the annual energy production cost (AEPC).

According to the calculations, the findings indicate that options 15 and 39 are the most suitable options for the implementation of appropriate SPKLUs. These alternatives involve the utilization of machines equipped with medium charging technology for outdoor land, accompanied by a business model adjustment 3. This adjustment entails power supply by PLN, investment in EV charger equipment by the private sector, absence of land lease, and operation and maintenance responsibilities undertaken by the private sector. The major difference between these two alternatives is in the establishment of location clusters. Specifically, option 15 focuses on the Mall's cluster, whereas option 39 centers around the parking lot area cluster. In addition, it was found that the appropriate implementation of SPBKLU is represented by option 1. This option entails the inclusion of three SGB storage boxes of machine swap batteries and two additional spare swap batteries.

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References

[1] G. Muhammad Rizki, A. Bintoro, and R. Hilmanto, "Perbandingan emisi karbon dengan karbon tersimpan di hutan rakyat Desa Buana Sakti Kecamatan Batanghari Kabupaten Lampung Timur," *Jurnal Sylva Lestari*, vol. 4, no. 1, pp. 89–96, 2016.

[2] M. Amin and M. Subri, "Uji performa filter gas emisi kendaraan bermotor berbasis keramik porous dengan aditif tembaga, tio 2 dan karbon aktif dalam penurunan kadar gas carbon monoksida," *Mekanika*, vol. 15, no. 2, 2016.

[3] Peraturan Presiden Republik Indonesia, *Peraturan Presiden Republik Indonesia Nomor 55 Tahun 2019 tentang Percepatan Program Kendaraan Bermotor Listrik Berbasis Baterai (Battery Electric Vehicle) untuk Transportasi Jalan*. 2019.

[4] A. Pramajaya and J. O. Haryanto, "Tacit knowledge and product information about the environmental impact towards the purchase intention of electric motorcycles," *Jurnal Teknik Industri:Jurnal Keilmuan dan Aplikasi Teknik Industri*, vol. 23, no. 2, pp. 149–160, Dec. 2021, doi: 10.9744/jti.23.2.149-160.

[5] G. Harrison and C. Thiel, "An exploratory policy analysis of electric vehicle sales competition and sensitivity to infrastructure in Europe," *Technol Forecast Soc Change*, vol. 114, pp. 165–178, Jan. 2017, doi: 10.1016/j.techfore.2016.08.007.

[6] Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia, *Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 1 Tahun 2023 tentang Penyediaan Infrastruktur Pengisian Listrik Untuk Kendaraan Bermotor Listrik Berbasis Baterai*. 2023.

[7] A. Ahmad, Z. A. Khan, M. Saad Alam, and S. Khateeb, "A review of the electric vehicle charging techniques, standards, progression and evolution of EV technologies in Germany," *Smart Science*, vol. 6, no. 1. Taylor and Francis Ltd., pp. 36–53, Jan. 02, 2018. doi: 10.1080/23080477.2017.1420132.

[8] M. R. Sarker, H. Pandžić, and M. A. Ortega-Vazquez, "Electric vehicle battery swapping station: Business case and optimization model," *2013 International Conference on Connected Vehicles and Expo (ICCVE)*, pp. 289–294, 2013, doi: 10.1109/ICCVE.2013.18.

[9] A. Widya, "Hasil riset catat jumlah SPBKLU di indonesia capai 1.700 Unit," viva.co.id. Accessed: Oct. 20, 2023. [Online]. Available: https://www.viva.co.id/otomotif/motor/1636860-hasil-riset-catat-jumlah-spbklu-di-indonesia-capai-1-700-unit

[10] D. Dananjaya and A. Ferdian, "Per September 2023, SPKLU di seluruh Indonesia tembus 846 unit," otomotif.kompas.com. Accessed: Oct. 20, 2023. [Online]. Available: https://otomotif.kompas.com/read/2023/09/08/164100415/per-september-2023-spklu-di-seluruh-indonesia-tembus-846-unit?page=all

[11] HE, "Populasi kendaraan listrik di Indonesia capai 81.525 Unit, ini rinciannya," beritasatu.com. Accessed: Oct. 20, 2023. [Online]. Available: https://www.beritasatu.com/ototekno/1065140/populasi-kendaraan-listrik-di-indonesia-capai-81525-unit-ini-rinciannya

[12] D. Hall and N. Lutsey, "emerging best practices for electric vehicle charging infrastructure", *The International Council on Clean Transportation (ICCT)*, 2017, [Online]. Available: www.theicct.org

[13] T. Adefarati, R. C. Bansal, and J. J. Justo, "Reliability and economic evaluation of a microgrid power system," in *Energy Procedia*, Elsevier Ltd, 2017, pp. 43–48. doi: 10.1016/j.egypro.2017.12.008.

[14] D. Balashov, "Techno-economic feasibility of pathways for an electric transition for petrol stations," University of Twente, 2021.

[15] S. Singh, P. Chauhan, and N. J. Singh, "Feasibility of grid-connected solar-wind hybrid system with electric vehicle charging station," *Journal of Modern Power Systems and Clean Energy*, vol. 9, no. 2, pp. 295–306, Mar. 2021, doi: 10.35833/MPCE.2019.000081.

[16] J. Martínez-Lao, F. G. Montoya, M. G. Montoya, and F. Manzano-Agugliaro, "Electric vehicles in Spain: An overview of charging systems," *Renewable and Sustainable Energy Reviews*, vol. 77. Elsevier Ltd, pp. 970–983, 2017. doi: 10.1016/j.rser.2016.11.239.

[17] S. Á. Funke, P. Plötz, and M. Wietschel, "Invest in fast-charging infrastructure or in longer battery ranges? A cost-efficiency comparison for Germany," *Appl Energy*, vol. 235, pp. 888–899, Feb. 2019, doi: 10.1016/j.apenergy.2018.10.134.

[18] S. Hosseini and M. D. Sarder, "Development of a Bayesian network model for optimal site selection of electric vehicle charging station," *International Journal of Electrical Power and Energy Systems*, vol. 105. Elsevier Ltd, pp. 110–122, Feb. 01, 2019. doi: 10.1016/j.ijepes.2018.08.011.

[19] M. Danial, F. A. Azis, and P. E. Abas, "Techno-economic analysis and feasibility studies of electric vehicle charging stations," *World Electric Vehicle Journal*, vol. 12, no. 4, Dec. 2021, doi: 10.3390/wevj12040264.

[20] A. Awasthi, K. Venkitusamy, S. Padmanaban, R. Selvamuthukumaran, F. Blaabjerg, and A. K. Singh, "Optimal planning of electric vehicle charging station at the distribution system using hybrid optimization algorithm," *Energy*, vol. 133, pp. 70–78, 2017, doi: 10.1016/j.energy.2017.05.094.

[21] Y. Krim, M. Sechilariu, F. Locment, and A. Alchami, "Global cost and carbon impact assessment methodology for electric vehicles' PV-powered charging station," *Applied Sciences (Switzerland)*, vol. 12, no. 9, May 2022, doi: 10.3390/app12094115.

[22] B. Borlaug, S. Salisbury, M. Gerdes, and M. Muratori, "Levelized cost of charging electric vehicles in the United States," *Joule*, vol. 4, no. 7, pp. 1470–1485, Jul. 2020, doi: 10.1016/j.joule.2020.05.013.

[23] L. Zhang, M. Yang, and Z. Zhao, "Game analysis of charging service fee based on benefit of multi-party participants: A case study analysis in China," *Sustain Cities Soc*, vol. 48, Jul. 2019, doi: 10.1016/j.scs.2019.101528.

[24] Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia, *Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 28 Tahun 2016 tentang Tarif Tenaga Listrik yang Disediakan oleh PT Perusahaan Listrik Negara (PERSERO)*. 2016.

[25] Redaksi JNEWS, "Kenali macam-macam sistem tukar baterai motor listrik," jnewsonline.com. Accessed: Aug. 19, 2023. [Online]. Available: https://jnewsonline.com/kenali-macam-macam-sistem-tukar-baterai-motor-listrik/2/

[26] L. Jian, Y. Zheng, and Z. Shao, "High efficient valley-filling strategy for centralized coordinated charging of large-scale electric vehicles," *Appl Energy*, vol. 186, pp. 46–55, Jan. 2017, doi: 10.1016/j.apenergy.2016.10.117.

[27] L. Zhang, Z. Zhao, H. Xin, J. Chai, and G. Wang, "Charge pricing model for electric vehicle charging infrastructure public-private partnership projects in China: A system dynamics analysis," *J Clean Prod*, vol. 199, pp. 321–333, Oct. 2018, doi: 10.1016/j.jclepro.2018.07.169.

[28] M. Yang, L. Zhang, and W. Dong, "Economic benefit analysis of charging models based on differential electric vehicle charging infrastructure subsidy policy in China," *Sustain Cities Soc*, vol. 59, Aug. 2020, doi: 10.1016/j.scs.2020.102206.

[29] Á. Cunha *et al.*, "Assessment of the use of vanadium redox flow batteries for energy storage and fast charging of electric vehicles in gas stations," *Energy*, vol. 115, pp. 1478–1494, Nov. 2016, doi: 10.1016/j.energy.2016.02.118.