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Techno-Economic Feasibility of EV Charging Station Deployment in Residential Buildings: A Condominium Case Study in Bangkok

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Abstract

The rapid growth of electric vehicle (EV) adoption in Thailand has increased demand for charging infrastructure, particularly at high-density residential buildings with parking and electrical-capacity constraints. This study evaluates the techno-economic feasibility of installing two 60 kW DC chargers and two 22 kW AC chargers at a condominium in Bangkok, with an initial investment of THB 1,990,500 excluding VAT. The assessment integrates project quotations, site-specific electrical designs, charger specifications, and scenario-based financial modeling. Technical feasibility was assessed based on installation requirements, electrical compatibility, and safety provisions, while economic feasibility was evaluated using net present value (NPV), internal rate of return (IRR), and simple payback period (PB). The proposed configuration satisfied the specified technical requirements. Three utilization scenarios considered DC charging for 4–6 h/day and AC charging for 10–14 h/day. Electricity costs were modeled at THB 4.50/kWh, with additional increases of 2.5% and 5% and corresponding adjustments to charging prices. A 10-year project lifetime and a 5.5% discount rate were assumed. The results showed NPVs ranging from THB 382,947.62 to THB 3,527,186.83, IRRs from 9.34% to 34.94%, and PBs from 2.72 to 6.32 years. The best-performing scenario, with DC and AC utilization of 6 and 14 h/day, respectively, achieved an NPV of THB 3,527,186.83, an IRR of 34.94%, and a PB of 2.72 years. Charger utilization, particularly DC utilization, was a key determinant of economic viability. Mixed AC/DC charging infrastructure may therefore be economically attractive under the modeled conditions, although the utilization assumptions were not validated using long-term measured charging-demand data.

Keywords: Electric vehicle charging station, residential EV charging, AC/DC chargers, techno-economic analysis, sensitivity analysis

1. Introduction

Electric vehicles (EVs) have attracted increasing attention globally as a promising pathway for reducing dependence on fossil fuels and mitigating greenhouse gas emissions from the transportation sector, driven by advances in battery technology, supportive public policies, and rising private-sector investment. In Thailand, this momentum is reflected by vehicle registration statistics, given that newly registered EVs rose from 5,857 in 2021 to 147,121 in 2025, while hybrid electric vehicles (HEVs) increased from 35,585 to 137,012 over the same period [1]. As EV adoption accelerates, expansion of the charging infrastructure has become an urgent priority.

Despite the momentum, widespread EV adoption cannot be fully realized without adequate and accessible charging infrastructure. While public fast-charging stations support intercity travel, residential charging is increasingly important for daily urban use — particularly in high-density environments such as condominiums,

where shared ownership arrangements, limited parking allocation, electrical-capacity constraints, and building management regulations prevent many residents from installing private chargers [2]. Consequently, planning shared EV charging systems in such settings has become both an infrastructure challenge and a critical engineering issue.

Previous research has assessed EV charging infrastructure from multiple perspectives, including power-system impacts, charger siting and sizing, user behavior, and financial feasibility. Financial performance is commonly evaluated using net present value (NPV), internal rate of return (IRR), and simple payback period (PB), with studies consistently identifying charger utilization, electricity tariff structure, and pricing strategy as key determinants of project viability. However, most existing literature focuses on public fast-charging stations or large-scale networks. Comparatively little attention has been given to mixed AC/DC charger deployment at high-density residential buildings, where installation constraints, electrical infrastructure readiness, and resident charging behavior must be considered simultaneously.

To address this gap in knowledge, this study investigates the techno-economic feasibility of installing EV charging stations at a Bangkok condominium using a mixed configuration of two 60 kW DC chargers and two 22 kW AC chargers. The analysis integrates actual project quotation data, site-specific electrical design information, charger specifications, and scenario-based financial modeling with sensitivity analysis. The findings are intended to provide practical guidance for investors, property managers, and policymakers seeking to expand residential EV charging infrastructure in alignment with urban mobility needs and long-term energy-transition goals.

2. Materials and methods

2.1 Electric Vehicles (EVs)

Electric vehicles (EVs) use electric motors powered by batteries or fuel cells as part or all of their propulsion system. They are generally classified into four main types, comprising hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs). Among these, PHEVs and BEVs are the most directly related to charging infrastructure because they require electricity from external charging systems. The rapid growth of these vehicle types has consequently increased the need for accessible and reliable charging facilities, particularly in urban residential areas where charging demand is concentrated.

2.2 EV Charging Stations

EV charging stations are essential infrastructure for supplying electricity to electric vehicles and are generally classified as either alternating current (AC) or direct current (DC) chargers. AC chargers supply power through the vehicle's onboard charger and are commonly used in residential and workplace settings because of their lower installation cost and suitability for longer parking durations. DC chargers deliver direct current straight to the battery, enabling much faster charging, thus making them more suitable for public, highway, and commercial applications. Charging may be conducted through either conductive cable connections or inductive wireless systems. However, conductive charging remains the dominant commercial approach because of its lower cost and greater technological maturity. DC-only and AC-only configurations were not evaluated in this study because project-specific quotation and infrastructure assumptions for alternative configurations were not available.

2.3 Economic Evaluation Methods

The economic feasibility of EV charging infrastructure is commonly evaluated using net present value (NPV), internal rate of return (IRR), and simple payback period (PB). NPV measures the present value of net project cash flow after accounting for the initial investment, with a positive value indicating financial feasibility. IRR represents the discount rate at which NPV equals zero and is generally considered acceptable when it exceeds the required rate of return. PB indicates the time required to recover the initial investment from project cash flow. Together, these indicators provide complementary measures of project value, profitability, and capital recovery and are therefore widely applied in techno-economic assessments of EV charging infrastructure.

Net present value (NPV) is a financial measure used to calculate the present value of a project's net cash inflow over its lifetime after subtracting the initial investment cost. It indicates whether an investment is economically worthwhile. A positive NPV implies that the project is financially feasible, whereas a negative NPV indicates that the project may not be economically attractive. The NPV is given by Equation (1).

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0 \quad (1)$$

where NPV is the net present value, n is the number of periods or years, t is the time period in which the cash flow occurs, C_t is the net cash flow in period t, r is the discount rate, and C_0 is the initial investment cost.

Internal rate of return (IRR) is the discount rate at which the net present value of a project becomes zero. It is a widely used indicator for evaluating the attractiveness of an investment because it reflects the expected rate of return over the project lifetime. The IRR is expressed as Equation (2).

$$0 = \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t} - C_0 \quad (2)$$

where IRR is the internal rate of return, n is the number of periods or years, t is the time period in which the cash flow occurs, C_t is the net cash flow in period t, and C_0 is the initial investment cost.

Simple Payback Period (PB) refers to the time required for a project to recover its initial investment from net cash inflow. It is a simple but useful indicator for assessing investment risk, particularly in projects where investors are concerned with how quickly capital can be recovered. The present value of annual cash flow can be calculated as Equation (3).

$$PV_t = \frac{C_t}{(1+r)^t} \quad (3)$$

where PV_t is the present value of cash flow in period t, C_t is the net cash flow in period t, r is the discount rate, and t is the time period.

These financial indicators are commonly used in infrastructure investment analysis because they provide complementary insights into project viability. Net present value (NPV) reflects the absolute financial value created by the project, while internal rate of return (IRR) represents the relative return on investment, and simple payback period (PB) indicates the speed of capital recovery. Taken together, these measures provide a comprehensive framework for evaluating the techno-economic feasibility of EV charging station projects [5], [6]. The economic feasibility criteria used in this study were based on conventional engineering-economic principles. A scenario was considered financially feasible when NPV was greater than zero, IRR exceeded the adopted interest rate of 5.5%, and PB was shorter than the assumed project lifetime.

2.4 Related Studies

Previous studies on EV charging infrastructure focused primarily on power-system impacts, including real-time charging coordination to reduce power losses, improve voltage profiles, and manage peak load in residential smart grids [7, 8]. As EV adoption expanded, research shifted toward the planning, siting, and sizing of charging stations to balance user convenience with distribution-network constraints [2, 9, 10]. A spatiotemporal optimization platform for charger placement in residential and non-residential settings was further developed by Li & Jenn [11], reflecting a broader transition from viewing charging stations as isolated assets to recognizing them as components of an integrated urban energy and transportation system.

Technical and regulatory barriers have also been widely identified as constraints on charger deployment at existing residential buildings. Condominiums and apartment complexes frequently face limitations related to electrical capacity, building-code compliance, and property management approval procedures [9, 12], making shared AC charging solutions increasingly important in practice.

The economic dimension of EV charging has attracted considerable attention, with financial feasibility commonly assessed using NPV, IRR, and PB alongside analyses of capital expenditure (CAPEX), operating expenditure (OPEX), utilization level, and pricing structure [13–15]. User behavior has also been shown to significantly influence financial outcomes, as charging decisions are closely associated with pricing schemes, spatial convenience, and access arrangements [16–18]. More recent studies have further emphasized dynamic and time-of-use (TOU) pricing as well as AI-based scheduling as means of improving both system performance and economic returns under variable demand conditions [19, 20].

In the Thai context, Chiradeja et al. [21] found that smaller charging stations, meaning those with one to three chargers, generally yield better financial returns than larger installations, and that electricity tariff differences significantly affect project viability. A subsequent field study at a 958-unit residential complex showed that charging demand peaked on weekdays between 19:00 and 22:00, standby power consumption was a notable

operational concern, and PB performance was highly sensitive to profit margin and utilization rate [22]. Together, these findings indicate that the deployment of financially sustainable residential EV charging requires accurate demand estimation, appropriate pricing, efficient operation, and careful consideration of local infrastructure constraints, all of which inform the analytical framework adopted in the present study. As summarized in Table 1 , previous techno-economic studies have focused mainly on public fast-charging stations, airport and highway applications, or renewable-energy-based systems incorporating PV and battery storage. These applications differ from high-density residential buildings in terms of charging demand, parking duration, electrical capacity, installation constraints, and operating patterns. Although some studies have examined residential EV charging, limited evidence is available on grid-connected mixed AC/DC charging configurations at existing condominiums using actual project quotation data and site-specific electrical information. Therefore, this study evaluates a mixed configuration of two 60 kW DC chargers and two 22 kW AC chargers at a Bangkok condominium to address this gap.

Table 1 Comparative Review of Recent Techno-Economic Studies on EV Charging Infrastructure

Study	Application	Charger/system	Energy source	Main economic assumptions	Key economic result	Difference from present study
Hasan et al. [23]	International airport, Bangladesh	Large EVCS, several hybrid configurations	Grid + PV + wind	Optimized by HOMER; tariff USD 0.14/kWh	Best hybrid case: PB ≈ 6.3 y	Airport-scale demand and renewable hybrid system
Elkholy et al. [24]	Public/commercial site, Cairo	DC/AC scenarios with PV/ESS	PV + ESS + grid/TOU	25-y lifetime	IRR 8.2%; PB 5.8 y for optimal case	Renewable hybrid public charging with storage
Hossain et al. [25]	Gazipur, Bangladesh	Solar EVCS	Solar PV	20-y project	NPV USD 652,656.8; IRR 11.7%; PB 7.2 y	Renewable-energy station rather than residential grid charging
Redwan et al. [26]	Expressway, Bangladesh	300 kWp EVCS, up to 20 EVs simultaneously	Off-grid PV	25-y lifetime	LCOE 7.1556 BDT/kWh	Highway/off-grid PV system
Hossain & Cho [27]	Global review of PV-powered EV charging	Various EVCS configurations	Solar PV, with/without grid/storage	Comparative review of cost, LCOE, NPV, IRR, and PB	Economic performance depends strongly on PV cost, utilization, tariff, and storage configuration	Reviews PV-powered EVCS rather than site-specific residential AC/DC deployment
Mouhy-Ud-Din et al. [28]	EV charging preferences, Pakistan	Home charging vs. Level 3 fast charging	Grid-connected	Survey-based charging behavior; HOMER Grid economic assessment	Charging preference affects load profile and economic performance	Focus on charging preferences, not mixed AC/DC residential deployment
Luo et al. [29]	Office building with EV parking, Chengdu, China	PV-building-EV integrated system with V2B	PV + grid + EV battery	Energy-sharing mechanisms including EV battery degradation and compensation	Reduced building LCOE by 38.9% and EV charging LCOE by 18.1%	Focuses on PV/V2B integration, not grid-connected residential charging
Chiradeja et al. [21]	Thailand EVCS	Various station sizes	Grid-connected	Tariff/utilization scenarios	Financial returns strongly depend on station size and tariff	Thai context but mainly charging-station operation
Chiradeja et al. [22]	Residential complex, Thailand	Residential EV charging	Grid-connected	Field demand and operational factors	PB sensitive to utilization and margin	Closest residential benchmark
Present study	Bangkok condominium	2 × 60 kW DC + 2 × 22 kW AC	Grid-connected	Actual quotation + site-specific design + scenario utilization	NPV, IRR and PB evaluated under condominium operating scenarios	Mixed AC/DC residential configuration under condominium constraints

2.5 Building Characteristics

In this study, a condominium complex comprising two 19-story buildings with a total of 950 residential units was selected as the case study. A site survey was carried out in the area near the building entrance and exit to

determine a suitable location for the installation of an EV charging station. This site was considered appropriate because its proximity to the main access points would enhance operational convenience and improve accessibility for both residents and visitors. In addition, the selected location is situated close to the electrical distribution room, thereby facilitating electrical connection and improving the practicality of charger installation. For the economic analysis, the combined fixed operating cost for land rental, maintenance, and personnel was assumed to be THB 40,000 per month. The technical feasibility assessment considered (1) suitability of the installation location, (2) connection to the condominium electrical system, (3) charger capacity and expected charging duration, (4) compatibility with commonly used EV charging interfaces, and (5) safety provisions. Feasibility was confirmed when these requirements could be satisfied within the proposed site and electrical design. A side view of the proposed structure is shown in Figure 1.

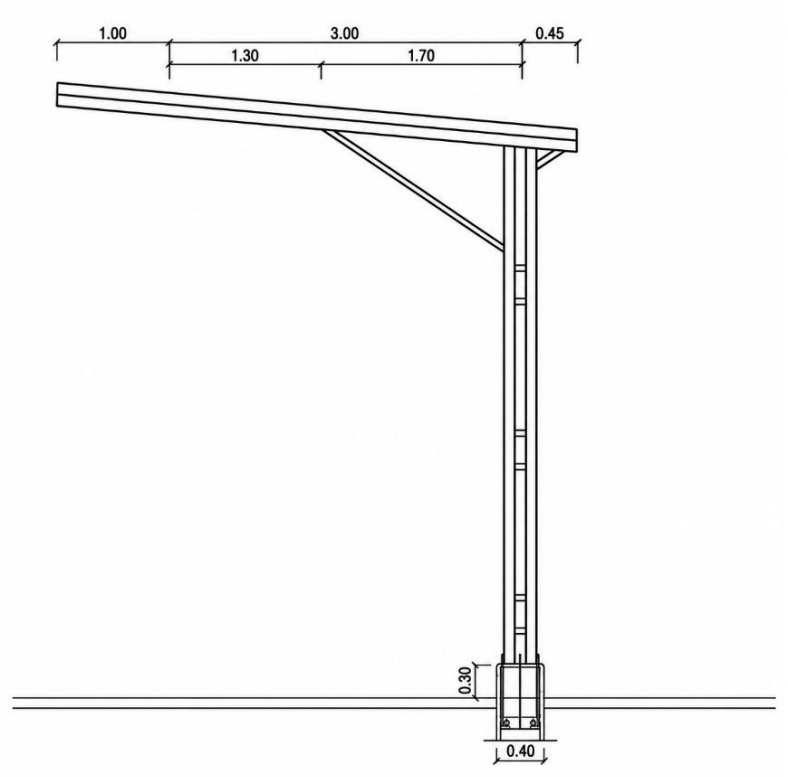


Figure 1 Side view of the proposed structural design for the EV charging station canopy

2.6 Quotation and Overall Specifications

The quotation adopted in this study represents the total initial capital expenditure required for the proposed EV charging station installation. The system consists of two 60 kW DC chargers and two 22 kW AC chargers, together with the necessary civil, electrical, and software components for implementation. The quoted items include parking-structure and canopy construction, charger installation works, electrical system installation, a 250 kVA transformer with installation, and a local-host software platform for EV charging station management.

The cost data were obtained from commercial quotations provided by an EV charging equipment supplier and installation contractor for the proposed condominium project. The quotation covers charging equipment, transformer installation, civil works, electrical installation, and charging-management software. Supplier identities are not disclosed for commercial confidentiality. All costs are reported in Thai baht at the quotation-year price level, as shown in Table 2. A single-line diagram of the proposed system is shown in Figure 2.

Table 2 Cost Breakdown and Specifications of the Proposed EV Charging Station

Equipment/work item	Quantity	Capacity/specification	Unit cost (THB)	Total cost (THB)
DC charger	2 units	60 kW/unit	347,750	695,500
AC charger	2 units	22 kW/unit	55,000	110,000
Transformer	1 unit	250 kVA	400,000	400,000
Civil works and canopy	1 lot	Parking/canopy structure	420,000	420,000
Electrical installation	1 lot	Electrical and charger installation	300,000	300,000
Software platform	1 system	Local-host management system	65,000	65,000
Total excluding VAT				1,990,500
Total including 7% VAT				2,129,835

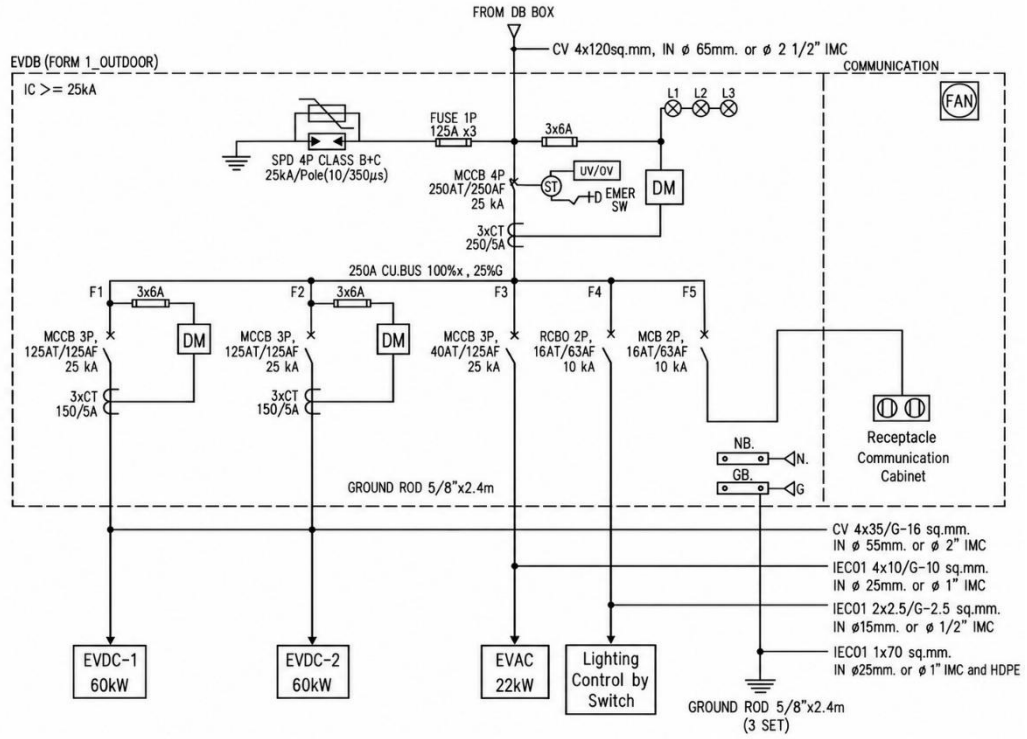


Figure 2 Single-line diagram of the proposed AC/DC EV charging station system

2.7 Construction Work

The structural work for installation of the proposed EV charging station included foundation preparation, canopy construction, and supporting installation components. The foundation work comprised site leveling, soil and debris removal, coarse sand filling, lean concrete (1:3:5), formwork, reinforcing steel bars (DB 12 mm and RB 6 mm), 1.25 mm steel tie wire, and cast-in-place concrete with a compressive strength of 240 kg/cm². The canopy structure consisted of a 0.35 mm metal-sheet roof supported by 4 × 4 inch steel columns with a thickness of 3.2 mm and C-channel steel members 100 × 50 × 20 × 2.3 mm in size. For corrosion protection, the steel members were coated with one layer of anti-rust primer and two layers of topcoat paint.

The installation-support elements included concrete wheel stops measuring 150 × 120 × 1800 mm, 3-inch square steel posts with a height of 800 mm and thickness of 2.3 mm, a 15 lb. fire extinguisher, and a fire-extinguisher cabinet. In addition, the lighting system comprises T8 LED fixtures rated at 18–20 W, 1200 mm in length, with IP65 lamp housings and IEC01 (THW) 2.5 sq.mm electrical wiring.

2.8 EV charger specification

The proposed charging system consists of 60 kW DC fast chargers and 22 kW AC chargers. The DC charger is equipped with two 5 m CCS connectors, supports an output of up to 200 A at 200–1000 VDC, and includes a 10.1-inch touchscreen, RFID authentication, Wi-Fi/Ethernet/4G connectivity, an emergency stop button, and OCPP support. The AC charger provides a 5 m Type 2 cable, RFID authentication, and Wi-Fi/Bluetooth/4G connectivity. Preventive maintenance is provided twice annually for two years. The data are shown in Table 3.

Table 3 Technical Specifications of the Proposed AC and DC EV Chargers

Specification	DC Charger	AC Charger
Charger type	DC fast charger	AC charger
Rated power	60 kW	22 kW
Connector	2 × CCS	1 × Type 2
Cable length	5 m	5 m
Output	200 A, 200–1000 VDC	Not specified
User authentication	RFID card reader	RFID card reader
Communication	Wi-Fi, Ethernet, 4G	Wi-Fi, Bluetooth, 4G
OCPP support	Yes	Not specified
Safety feature	Emergency stop button	Not specified
Preventive maintenance	Twice/year for 2 years	Twice/year for 2 years

3. Results

For financial analysis, several assumptions were established to construct the case studies. For example, it was assumed that each electric vehicle would be charged to approximately 85% state of charge, corresponding to an average energy demand of about 40 kWh per charging session. For the 60-kW DC charger, each session lasted about 40–50 min. In practice, however, the charging rate of DC chargers gradually decreases during the later stage of charging because of the tapering effect used to protect battery health. By contrast, a 22 kW AC charger generally requires approximately 3–4 h per charging session, depending on the onboard charger (OBC) capacity of the vehicle. Based on these technical assumptions, the sensitivity cases were designed to reflect realistic operating conditions for scenario modeling purposes; the proportion of EV users in the building was assumed to be approximately 40% of residents.

In Sensitivity Case 1, the charging system consisted of two 60 kW DC chargers and two 22 kW AC chargers. The DC chargers were assumed to operate for 4 h/day, while the AC chargers were evaluated at 10, 12, and 14 h/day. The operating hours represent equivalent daily charger utilization used for financial scenario modeling rather than continuous charging of a single vehicle.

The electricity cost was set at THB 4.50/kWh in the base case and increased by 2.5% and 5% in the sensitivity analysis. The charging service price was initially set at THB 6.90/kWh and adjusted proportionally with the electricity cost. To illustrate the financial calculation procedure, the first operating scenario in Table 4 was selected, with DC and AC charger utilization of 4 and 10 h/day, respectively. Under an electricity cost of THB 4.50/kWh and a charging price of THB 6.90/kWh, the estimated annual net cash flow was THB 314,880. Using Equation (1), the calculated NPV was THB 382,947.62. The IRR, obtained from Equation (2), was approximately 9.34%, while the PB calculated using Equation (3) was 6.32 years. These calculations illustrate the procedure applied consistently to the remaining scenarios presented in Table 4.

Table 4 Financial results for sensitivity Case 1

DC h/day	AC h/day	Electricity cost (THB/kWh)	Selling price (THB/kWh)	Annual net cash flow (THB)	NPV (THB)	IRR (%)	Simple Payback Period (years)
4	10	4.5000	6.9000	314,880.00	382,947.62	9.34	6.32
4	10	4.6125	7.0725	334,752.00	532,735.32	10.77	5.95
4	10	4.7250	7.2450	354,624.00	682,523.02	12.16	5.61
4	12	4.5000	6.9000	390,912.00	956,048.39	14.62	5.09
4	12	4.6125	7.0725	412,684.80	1,120,163.61	16.06	4.82
4	12	4.7250	7.2450	434,457.60	1,284,278.83	17.46	4.58
4	14	4.5000	6.9000	466,944.00	1,529,149.15	19.51	4.26
4	14	4.6125	7.0725	490,617.60	1,707,591.89	20.98	4.06
4	14	4.7250	7.2450	514,291.20	1,886,034.63	22.42	3.87

In Sensitivity Case 2, the same charging configuration was maintained, but the DC charger operating time was increased to 5 h/day, while the AC chargers were again assumed to operate for 10, 12, and 14 h/day. The same electricity-cost assumptions were applied, with a base value of THB 4.50/kWh and sensitivity increases of 2.5% and 5%. Similarly, the charging service price was set at THB 6.90/kWh and adjusted in line with electricity-cost variation. The results for this case are presented in Table 5.

Table 5 Financial results for sensitivity Case 2

DC h/day	AC h/day	Electricity cost (THB/kWh)	Selling price (THB/kWh)	Annual net cash flow (THB)	NPV (THB)	IRR (%)	Simple Payback Period (years)
5	10	4.5000	6.9000	418,560.00	1,164,448.67	16.44	4.76
5	10	4.6125	7.0725	441,024.00	1,333,773.89	17.88	4.51
5	10	4.7250	7.2450	463,488.00	1,503,099.12	19.30	4.29
5	12	4.5000	6.9000	494,592.00	1,737,549.43	21.22	4.02
5	12	4.6125	7.0725	518,956.80	1,921,202.18	22.70	3.84
5	12	4.7250	7.2450	543,321.60	2,104,854.93	24.16	3.66
5	14	4.5000	6.9000	570,624.00	2,310,650.20	25.77	3.49
5	14	4.6125	7.0725	596,889.60	2,508,630.47	27.30	3.33
5	14	4.7250	7.2450	623,155.20	2,706,610.73	28.82	3.19

In Sensitivity Case 3, the charging system again consisted of two 60 kW DC chargers and two 22 kW AC chargers, but the DC chargers were assumed to operate for 6 h/day, while the AC chargers were assumed to operate for 10, 12, and 14 h/day. The same assumptions regarding electricity cost and charging service price were applied. The results for this case are presented in Table 6.

Table 6 Financial results for sensitivity Case 3

DC h/day	AC h/day	Electricity cost (THB/kWh)	Selling price (THB/kWh)	Annual net cash flow (THB)	NPV (THB)	IRR (%)	Simple Payback Period (years)
6	10	4.5000	6.9000	522,240.00	1,945,949.71	22.90	3.81
6	10	4.6125	7.0725	547,296.00	2,134,812.47	24.40	3.64
6	10	4.7250	7.2450	572,352.00	2,323,675.22	25.87	3.48
6	12	4.5000	6.9000	598,272.00	2,519,050.48	27.38	3.33
6	12	4.6125	7.0725	625,228.80	2,722,240.75	28.94	3.18
6	12	4.7250	7.2450	652,185.60	2,925,431.02	30.47	3.05
6	14	4.5000	6.9000	674,304.00	3,092,151.25	31.72	2.95
6	14	4.6125	7.0725	703,161.60	3,309,669.04	33.34	2.83
6	14	4.7250	7.2450	732,019.20	3,527,186.83	34.94	2.72

The results show an apparent relationship between charger utilization and financial performance. As DC charger operating time increased from 4 to 6 h/day, annual net cash flow, NPV, and IRR increased consistently, while PB decreased. A similar improvement was observed when AC charger operating time increased from 10 to 14 h/day. This pattern indicates that charger utilization is a major determinant of project profitability because higher utilization increases the amount of electricity sold, whereas a substantial proportion of project costs remains fixed.

Across all operating conditions, Case 3 consistently produced stronger financial performance than Cases 1 and 2, while Case 1 produced the lowest returns. The difference was primarily attributable to the additional utilization of the DC chargers, which have higher charging power and therefore greater potential energy throughput per operating hour. Nevertheless, the results should be interpreted as conditional on the assumed utilization, electricity cost, and selling-price scenarios rather than as guaranteed financial outcomes.

The sensitivity results also indicate that the project remains more financially attractive under higher-utilization conditions, whereas lower charger utilization leads to lower cash flow, lower NPV and IRR, and a longer PB. This finding emphasizes the importance of demand concentration, charger availability, and effective operational planning in maintaining sufficient utilization of the charging infrastructure. The findings are consistent with previous studies in Thailand, which identified charger utilization, electricity tariffs, and operating margin as key determinants of financial feasibility [21], [22]. However, the present study specifically evaluates a grid-connected mixed AC/DC system at a high-density condominium using project-specific cost and electrical-design data. Figure 3 provides a numerical summary of the main contribution of this study by comparing the best-performing scenario in each sensitivity case using three key financial indicators: net present value (NPV), internal rate of return (IRR), and simple payback period (PB). The results show a distinct and consistent improvement in project performance as DC charger utilization increases. In the best scenario of Case 1, the project achieved an NPV of THB 1.89 million, an IRR of 22.42%, and a PB of 3.87 years. In Case 2, the corresponding values improved to THB 2.71 million, 28.82%, and 3.19 years, respectively. The strongest performance was observed in Case 3, where the project generated an NPV of THB 3.53 million, an IRR of 34.94%, and a PB of 2.72 years.

These results demonstrate that charger-utilization level, particularly for DC chargers, is a critical determinant of the techno-economic feasibility of residential EV charging infrastructure. As utilization increases, both NPV and IRR rise substantially, while PB decreases, indicating faster capital recovery and greater investment attractiveness. Therefore, Figure 3 highlights the practical contribution of this study by showing that a mixed AC/DC charging configuration in a condominium setting can become highly viable when supported by appropriate operating conditions, utilization levels, and infrastructure planning. The least favorable scenario occurred under the lowest charger utilization and base electricity-price conditions, whereas the most favorable scenario was observed at the highest charger utilization. The comparison between these two extremes confirms that project performance is highly sensitive to charger utilization, with higher utilization substantially improving NPV and IRR, while shortening PB.

The project-lifetime sensitivity analysis showed that increasing the project period from 8 to 15 years increased NPV and IRR in all three cases, whereas the PB remained unchanged. Case 3 consistently achieved the strongest financial performance across all project lifetimes, followed by Cases 2 and 1. This indicates that the comparative ranking of the operating cases is robust to changes in the assumed project lifetime. The results for this case are presented in Table 7.

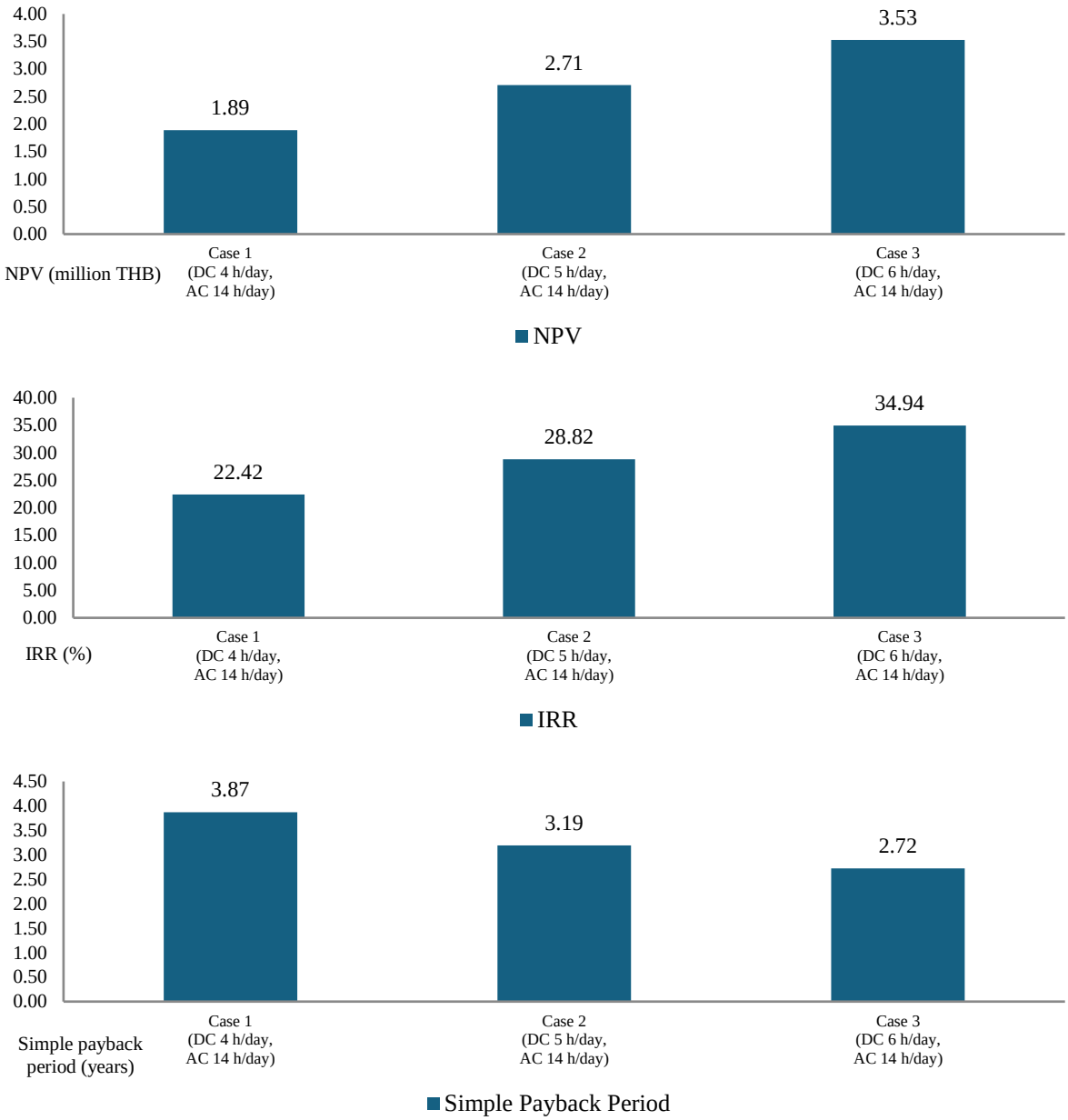


Figure 3 Numerical summary of the main contribution of the study, comparing the best-performing scenario in each sensitivity case in terms of NPV, IRR, and PB

Table 7 Sensitivity Analysis of Project Lifetime for the Best-Performing Scenario in Each Case

Case	Project lifetime (years)	NPV (THB)	IRR (%)	Simple PB (years)
Case 1	8	1,267,311.54	19.71	3.87
	10 (Base case)	1,886,034.63	22.42	3.87
	15	3,171,739.55	24.92	3.87
Case 2	8	1,956,917.74	26.55	3.19
	10 (Base case)	2,706,610.73	28.82	3.19
	15	4,264,470.76	30.75	3.19
Case 3	8	2,646,523.93	33.03	2.72
	10 (Base case)	3,527,186.83	34.94	2.72
	15	5,357,201.97	36.43	2.72

A possible explanation for this trend is that DC chargers contribute disproportionately to project revenue because they deliver higher charging power and can serve more vehicles within a shorter time period than AC chargers. When DC charger operating hours increase from 4 to 6 h/day, the charging station can support more charging sessions and generate higher daily income, while many fixed costs, such as land rental, personnel, and part of the maintenance cost, remain unchanged. This improves overall cash flow and leads to higher NPV and IRR values together with a shorter PB. Therefore, the results suggest that, in residential condominium settings,

project success depends not only on the installation of the charging equipment but also on achieving sufficient charger utilization, especially for DC fast charging. From a practical standpoint, this implies that site selection, user demand concentration, pricing strategy, and operational planning are essential factors for improving the financial performance and long-term sustainability of EV charging infrastructure.

4. Conclusion

This study investigated the techno-economic feasibility of installing EV charging stations at high-density residential condominiums in Bangkok using a selected condominium project as the case study. The proposed system consisted of two 60 kW DC chargers and two 22 kW AC chargers, with an initial investment cost of THB 1,990,500 excluding VAT. The results showed that all evaluated scenarios across the three sensitivity cases were financially feasible under the assumed conditions, as positive NPV values were obtained in all scenarios. However, project performance varied according to charger utilization, particularly the operating hours of the DC chargers. Case 3, in which the DC chargers operated for 6 h/day and the AC chargers operated for 10–14 h/day, produced the best overall performance, with a maximum NPV of THB 3,527,186.83, an IRR of 34.94%, and a PB of 2.72 years. These findings indicate that charger utilization level, especially DC charger utilization, is a critical determinant of the techno-economic viability of residential EV charging infrastructure.

From a practical perspective, the study suggests that the EV charging infrastructure at condominiums can be economically attractive when supported by appropriate site selection, adequate electrical capacity, and effective operational planning. The selected installation area, located near the building entrance and electrical distribution room, was advantageous in terms of both user accessibility and installation practicality. Charger downtime and declining utilization would reduce the amount of electricity sold and therefore lower annual cash flow, NPV, and IRR while extending the PB. This effect is especially important for DC chargers because their higher capital cost requires sufficient utilization to maintain financial performance. This study was limited to a single condominium in Bangkok and relied on scenario-based charger utilization rather than long-term measured demand. Actual downtime, equipment degradation, and replacement needs may also differ from the model assumptions. Future studies should validate the findings using long-term data from multiple residential buildings. Increased charger operating time also has technical implications. Although the rated charger capacity remains unchanged, longer operating periods increase cumulative electrical loading and thermal duty, and may increase simultaneous demand on the building electrical system. Therefore, transformer loading, protection systems, thermal conditions, and charger availability should be monitored as utilization increases. Future research should incorporate long-term observed charging behavior, alternative pricing strategies such as time-of-use or dynamic pricing, and technical analysis of load management and grid impacts. Comparative studies involving different building types and charger configurations would further strengthen the generalizability of the findings and support wider deployment of residential EV charging infrastructure in urban areas.

5. Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the authors used ChatGPT (version 5.5, OpenAI) to improve the clarity, tone, and grammar of sentences and to organize the literature review. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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7. Author Contributions

C.K. and L.R. contributed to conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, resources, software, validation, visualization, writing – original draft, and writing – review & editing. P.A. and P.L. contributed to funding acquisition, investigation, methodology, project administration, validation, visualization, writing – original draft, and writing – review & editing. All authors have read and agreed to the published version of the manuscript.

8. References

[1] Department of Land Transport. Annual transport statistics report for fiscal year 2024. Bangkok: Department of Land Transport; 2025.

[2] Mishra S, Verma S, Chowdhury S, Gaur A, Mohapatra S, Dwivedi G, et al. A comprehensive review on developments in electric vehicle charging station infrastructure and present scenario of India. Sustainability. 2021;13(4):2396.

[3] Chadderton RA. Purposeful engineering economics. Cham: Springer International Publishing; 2015.

[4] Newnan DG, Eschenbach TG, Lavelle JP. Engineering economic analysis. 13th ed. New York (NY): Oxford University Press; 2017.

[5] Brigham EF, Ehrhardt MC. Financial management: theory & practice. 16th ed. Boston (MA): Cengage Learning; 2016.

[6] Brealey RA, Myers SC, Allen F. Principles of corporate finance. 12th ed. New York (NY): McGraw-Hill Education; 2017.

[7] Deilami S, Masoum AS, Moses PS, Masoum MAS. Real-time coordination of plug-in electric vehicle charging in smart grids to minimize power losses and improve voltage profile. IEEE Trans Smart Grid. 2011;2(3):456-467.

[8] Ul Hassan NU, Khalid YI, Yuen C, Tushar W. Customer engagement plans for peak load reduction in residential smart grids. IEEE Trans Smart Grid. 2015;6(6):3029-3041.

[9] Al-Hanahi B, Ahmad I, Habibi D, Masoum MAS. Charging infrastructure for commercial electric vehicles: Challenges and future works. IEEE Access. 2021;9:121476-121492.

[10] Unterluggauer T, Rich J, Andersen PB, Hashemi S. Electric vehicle charging infrastructure planning for integrated transportation and power distribution networks: A review. eTransportation. 2022;12:100163.

[11] Li X, Jenn A. An integrated optimization platform for spatial-temporal modeling of electric vehicle charging infrastructure. Transp Res Part D Transp Environ. 2022;104:103177.

[12] Carvalhosa S, Ferreira JR, Araújo RE. Electric vehicle charging method for existing residential condominiums. IEEE Access. 2024;12:166537-166552.

[13] George-Williams H, Wade N, Carpenter RN. A probabilistic framework for the techno-economic assessment of smart energy hubs for electric vehicle charging. Renew Sustain Energy Rev. 2022;162:112386.

[14] Miao R, Guo P, Huang W, Li Q, Zhang B. Profit model for electric vehicle rental service: Sensitive analysis and differential pricing strategy. Energy. 2022;249:123736.

[15] Bernal D, Raheem AA, Inti S, Wang H. Assessment of economic viability of direct current fast charging infrastructure investments for electric vehicles in the United States. Sustainability. 2024;16(15):6701.

[16] Visaria AA, Jensen AF, Thorhauge M, Mabit SE. User preferences for EV charging, pricing schemes, and charging infrastructure. Transp Res Part A Policy Pract. 2022;165:120-143.

[17] Budnitz H, Meelen T, Schwanen T. Public residential charging of electric vehicles: An exploration of UK user preferences. Eur Transp Stud. 2024;1:100004.

[18] Kuang H, Zhang X, Qu H, You L, Zhu R, Li J. Unraveling the effect of electricity price on electric vehicle charging behavior: A case study in Shenzhen, China. Sustain Cities Soc. 2024;115:105836.

[19] Chen Q, Folly KA. Application of artificial intelligence for EV charging and discharging scheduling and dynamic pricing: A review. Energies. 2022;16(1):146.

[20] Narayan A, Krishna A, Misra P, Vasan A, Sarangan V. A dynamic pricing system for electric vehicle charging management using reinforcement learning. IEEE Intell Transp Syst Mag. 2022;14:122-134.

[21] Chiradeja P, Sottiyaphai C, Ngaopitakkul A, Ananwattanaporn S. Financial feasibility of electric vehicle charging stations in Thailand: An analysis of operational models and energy costs. Energy Strategy Rev. 2025;60:101785.

[22] Chiradeja P, Yoomak S, Sottiyaphai C, Ngaopitakkul A, Klomjit J, Ananwattanaporn S. Analysis of investment feasibility for EV charging stations in residential buildings. Appl Sci. 2025;15(17):9716.

[23] Hasan S, Zeyad M, Ahmed SMM, Mahmud DM, Anubhove MST, Hossain E. Techno-economic feasibility analysis of an electric vehicle charging station for an International Airport in Chattogram, Bangladesh. Energy Convers Manag. 2023;293:117501.

[24] Elkholy MM, Abd El-Raouf A, Farahat MA, Lotfy ME. Design and techno-economic feasibility study of a solar-powered EV charging station in Egypt. Electricity. 2025;6(3):50.

[25] Hossain MN, Hasan MM, Habib MA, Ferdous FB, Rahman S. Assessing economic viability and environmental impact of solar-powered EV charging station in Gazipur, Bangladesh: A case study. Solar Compass. 2024;12:100091.

[26] Redwan R, Hasan M, Nadia A, Khan MS, Chowdhury NA, Chowdhury NUR. Design analysis and techno-economic assessment of a photovoltaic-fed electric vehicle charging station at Dhaka-Mawa expressway in Bangladesh. Energy Convers Manag X. 2024;24:100737.

[27] Hossain MN, Cho HM. Techno-economic feasibility of photovoltaic-powered electric vehicle charging stations: a global review and future outlook. Sustain Energy Res. 2026;13:9.

[28] Mouhy-Ud-Din MA, Azeem F, Memon Z, Arshad J. Comparative techno-economic assessment of electric vehicle charging preferences: A quantitative study for sustainable EV policy in Pakistan. Energy Sustain Dev. 2024;78:101355.

[29] Luo J, Cao X, Yuan Y. Comprehensive techno-economic performance assessment of PV-building-EV integrated energy system concerning V2B impacts on both building energy consumers and EV owners. J Build Eng. 2024;87:109075.