

HOMER-Based Techno-Economic Analysis of a Solar-Powered EV Charging Station for Campus Use

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Abstract: *The electrification of campus transportation requires charging infrastructure capable of accommodating variable charging demand while controlling energy cost, grid dependence and environmental impact. This paper presents a HOMER-based techno-economic analysis of a solar-powered electric vehicle (EV) charging station for campus use. The proposed architecture, derived from the supplied thesis, integrates a 60 kW DC solar photovoltaic (PV) array, maximum-power-point-tracking and DC–DC conversion, a 70 kW power-conversion/inverter stage, a 100 kWh lithium-iron-phosphate battery energy storage concept, Level-2 EV charging, utility-grid support and an energy-management strategy. The HOMER results report annual EV charging consumption of 1,09,500kWh/year [300kW×365] out of total campus consumption of 884,852 kWh, solar PV production of 115,588 kWh and grid purchases of 774,118 kWh. The model reports 37.4 kWh/year of excess electricity, zero unmet electric load and zero capacity shortage. The annual renewable fraction is 12.5% w.r.t total load & 100% w.r.t EV Charging load, while maximum instantaneous renewable penetration reaches 93.2%. The reported economic indicators are a total net present cost (NPC) of \$1,633,301, levelized cost of energy (LCOE) of \$0.1428/kWh, annual operating cost of \$90,771.55, ROI of 16.78% and payback period of 5.95 years. The emissions output is 489,243 kg CO₂/year, 2,121 kg SO₂/year and 1,037 kg NO_x/year. The paper also performs transparent consistency checks on the reported economic and energy-balance values and identifies modeling issues requiring clarification before practical deployment, particularly the relationship between the stated 100 kW charging envelope and the higher instantaneous load peaks shown in the time-series output, the treatment of the 100 kWh BESS in the base-case results, and the use of an effectively unconstrained grid connection. The study provides a structured simulation-based assessment of solar-assisted campus EV charging and establishes a basis for future validation using measured campus charging data.*

Keywords: Electric vehicle charging; solar photovoltaic; HOMER Pro; techno-economic analysis; campus energy system; renewable fraction; grid interaction; LCOE; net present cost; battery energy storage.

I. INTRODUCTION

The rapid adoption of electric vehicles is creating a corresponding requirement for dependable charging infrastructure. Conventional grid-dependent charging stations can increase electricity demand during periods of simultaneous charging and may create operational and economic challenges. Integrating renewable generation with EV charging provides an approach for supplying part of the charging demand from locally available clean energy. The supplied thesis identifies



educational campuses as suitable locations because vehicle activity, parking duration and daytime energy use can provide opportunities for solar-powered charging.

The thesis specifically addresses the design and performance analysis of a solar-powered EV charging station using HOMER. Its stated research objectives include reviewing EV charging and PV technologies, estimating campus EV charging demand, designing the PV-based charging station, examining operation under different irradiance and charging-demand conditions, and developing a reliable and environmentally sustainable charging concept for educational campuses. The work also formulates the design problem around reducing charging cost, reducing grid dependence, maintaining BESS operation within safe SOC limits and reducing emissions.

The present paper narrows the thesis into a journal-style techno-economic case study. Rather than reproducing the thesis chapter-by-chapter, the analysis integrates the technical architecture, annual energy balance, time-series behavior, economic indicators and environmental outputs into a single reproducible results framework.

1.1 Research contributions

Contribution	Description
Campus-oriented system model	Solar PV, BESS, EV charging, conversion, grid and EMS are considered as an integrated architecture.
HOMER-based annual assessment	Annual production, consumption, grid purchases, renewable fraction and reliability indicators are quantified.
Techno-economic assessment	NPC, LCOE, operating cost, ROI and payback are reported and cross-checked.
Environmental assessment	CO ₂ , SO ₂ and NO _x outputs are documented together with the thesis CO ₂ -avoidance calculation.
Reproducibility review	Internal numerical and configuration ambiguities are explicitly identified rather than hidden.

II. LITERATURE AND RESEARCH CONTEXT

The thesis references prior research on PV-integrated EV charging, EV load management, battery storage, power electronics, MATLAB/Simulink modeling and renewable-energy systems. In particular, the supplied references include university-scale PV/grid EV charging, solar PV integrated EV charging infrastructure, grid-integrated solar EV charging with battery storage, and EV charging energy-management strategies. These studies establish the technical basis for integrating renewable generation, storage and grid support in EV charging applications.

The research gap addressed by the thesis is the application of this integrated approach to educational campuses, where charging demand is shaped by academic schedules, daytime parking and potentially repeatable arrival and departure patterns. The thesis therefore emphasizes campus EV load estimation, solar resource assessment, PV sizing, BESS design and HOMER-based performance evaluation.

For a journal paper, the important distinction is that the present work is a case-study simulation rather than an experimental demonstration. The results should consequently be interpreted as model outputs under the stated assumptions.

III. SYSTEM DESCRIPTION AND METHODOLOGY

3.1 Proposed architecture

The proposed architecture contains a solar PV subsystem, MPPT controller, DC–DC converter, BESS, inverter, EV charging unit, utility-grid connection and energy-management system. Solar PV is treated as the principal renewable source, while the battery and grid provide support when solar generation is insufficient or charging demand is high. The methodology in the thesis follows campus EV load assessment, solar resource analysis, PV sizing, battery storage design, power-electronic modeling, HOMER modeling and performance evaluation.



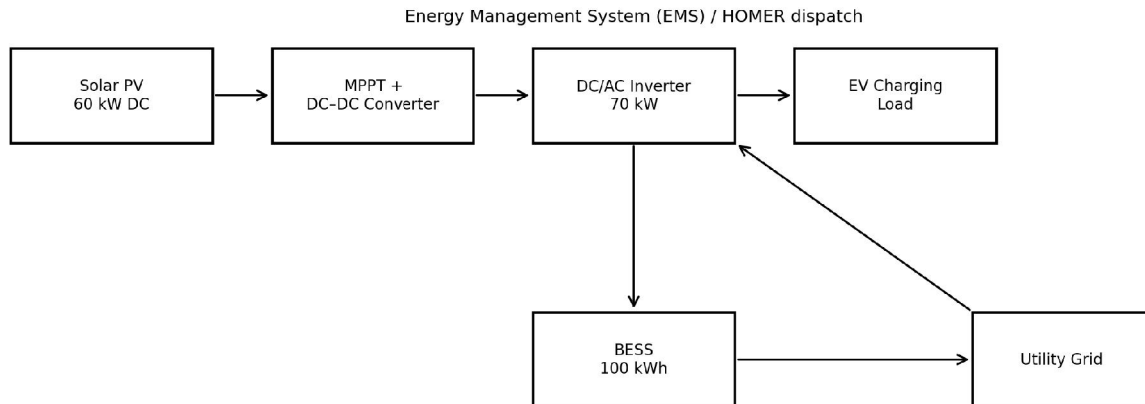


Figure 1. Conceptual hybrid solar-powered EV charging architecture reconstructed from the system architecture described in the supplied thesis.

3.2 Main simulation parameters

Table 1: Key parameters for a 100 kW PV/grid-integrated EVCS

Parameter Category	Description	Values/Considerations
PV System Parameters	Solar PV Capacity	60 kW DC
	Number of PV Panels	~200 panels (assuming 500 W per panel)
	Area Required	375–500 m ²
	Tilt Angle & Orientation	25°–30° tilt, south-facing (in Northern Hemisphere)
	Solar Irradiance	~5–5.5 kWh/m ² /day
EV Charging Load Parameters	Charging Station Capacity	100 kW AC
	Number of Chargers	4 chargers (25 kW each) or 10 chargers (10 kW each)
	Charger Types	Level 2 (7.2–22 kW)
	Connector Types	Type 2
Energy Storage System (ESS)	Battery Capacity	100 kWh
	Battery Type	Lithium-ion Phosphate (LiFePO ₄)
	SOC Control	SOC limits between 20 % and 80 %
Inverter Parameters	Inverter Size	70 kW AC
	Inverter Type	Hybrid
	Inverter Efficiency	95 %–98 %
Energy Generation & Demand	Daily Energy Generation	~317 kWh/day (based on 6 h/day of sunlight)
	Energy Consumption (per EV)	~15–30 kWh per charge
	Daily EV Energy Demand	~300 kWh/day (for 10 EVs at 30 kWh/charge)
Grid Connection Parameters	Grid Connection Capacity	999,999 kW
Economic & Financial Parameters	Capital Cost	\$250,000
	Operation & Maintenance Costs	\$90,771.55



The above values are retained from the thesis rather than replaced with new design assumptions. The annual HOMER outputs used in the results section are taken from the supplied simulation screenshots and thesis results pages.

3.3 HOMER dispatch and energy management

The thesis specifies the HOMER Cycle Charging algorithm for the grid-tied configuration. Renewable energy is prioritized to serve the AC primary load, while grid supply supplements the load when PV generation is insufficient. The overall EMS concept coordinates PV generation, battery storage, EV demand and utility-grid support.

The annual energy relationship is expressed as:

$$E_{PV} + E_{grid} = E_{load} + E_{excess} + E_{other}$$

where E_{other} represents conversion, system or accounting differences not separately identified in the supplied annual summary. Using the reported values, the remaining difference after accounting for PV, grid, load and excess electricity is approximately 4,817.6 kWh/year. Because the source does not explicitly assign this quantity to a named loss category, this paper does not attribute it to a specific component.

IV. RESULTS

4.1 Annual electrical production and consumption

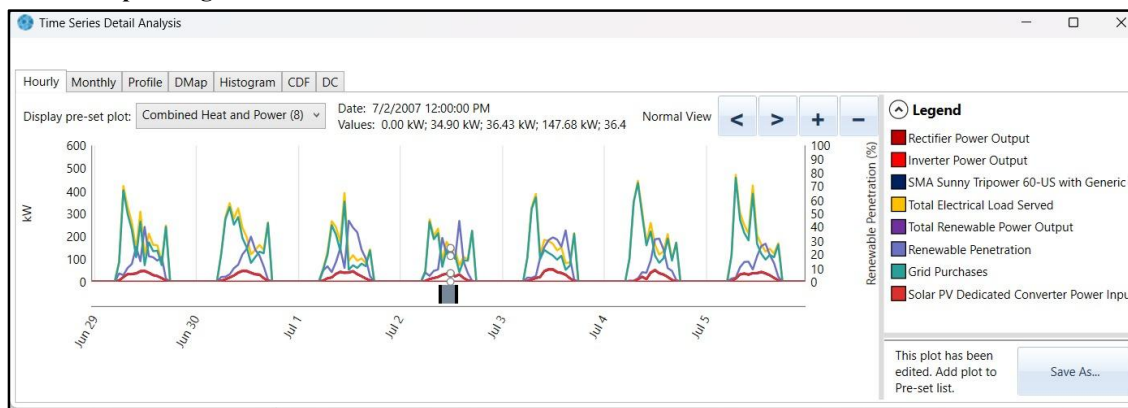
Solar PV contributes 115.588 MWh/year, while the grid supplies 774.118 MWh/year. Relative to the annual campus



load of EV charging load, PV production corresponds to approximately 13.06%. The HOMER renewable-fraction metric is reported separately as 12.5% w.r.t total campus load & 100% w.r.t EV charging load; both figures are retained because they arise from different definitions/accounting bases.



4.2 Time-series operating behavior



The supplied HOMER time-series output for a representative week from June 29 to July 5 shows repeated daytime charging peaks. The supplied screenshot visibly contains peaks approaching the 400–450 kW range. The 60 kW PV output follows daylight availability, and grid purchases closely track the total load because the instantaneous demand is much greater than the PV rating.

The time-series behavior explains the difference between annual renewable fraction and maximum renewable penetration. The thesis also reports only 37.4 kWh/year of excess electricity, indicating strong direct utilization of PV generation.

4.3 Economic results

Economic indicator	Reported value
Capital cost	\$250,000
Annual operating cost	\$90,771.55
LCOE	\$0.1428/kWh
Total NPC	\$1,633,301.00
ROI	16.78%
Payback period	5.95 years

The thesis's illustrative conventional-grid comparison uses a tariff of approximately \$0.15/kWh. Applying this tariff to the reported annual load gives a reference annual electricity cost of \$132,727.80. The difference between this reference and the reported hybrid operating cost is approximately \$41,956.25/year. The corresponding simple payback is approximately 5.96 years (\$250,000/\$41,956.25), closely matching the reported 5.95 years. This is an arithmetic consistency check and should not be confused with HOMER's discounted life-cycle calculation.

The NPC and LCOE values should be interpreted together with the underlying economic assumptions. The thesis reports the capital cost and operating cost, but the journal version should also state project lifetime, discount rate, replacement schedule and tariff assumptions explicitly if the model is to be independently reproduced.



4.4 Environmental results

The thesis calculates approximately 94.78 tonnes/year of CO₂ avoided by applying a 0.82 kg CO₂/kWh factor to

Simulation Results		
System Architecture:	Grid (999,999 kW)	
SMA Sunny Tripower 60-US with Generic PV (60.0 kW/60.0 kW)	HOMER Cycle Charging	
CAT BDI-SI-3Ph (70.0 kW)		
		? Total NPC: \$1,633,301.00
		? Levelized COE: \$0.1428
		? Operating Cost: \$90,771.55
Cost Summary	Cash Flow	Compare Economics
Electrical	Renewable Penetration	SMA Sunny Tripower 60-US with Generic PV
Grid	CAT BDI-SI-3Ph	Emissions
Quantity	Value	Units
Carbon Dioxide	489,243	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	2,121	kg/yr
Nitrogen Oxides	1,037	kg/yr

115,588 kWh/year of PV generation. This external-factor calculation should be reported separately from the raw HOMER emissions output. The thesis also provides a 100%-grid counterfactual, but the two approaches use different accounting bases and should not be combined into one avoided-emissions figure without a defined system boundary.

4.5 Renewable contribution

The annual renewable fraction of 12.5% indicates that the PV system supplies a limited but measurable share of annual energy demand, whereas the maximum renewable penetration of 93.2% demonstrates that PV can dominate instantaneous supply during favorable combinations of irradiance and charging demand. These are complementary indicators and should be reported together.

V. DISCUSSION

5.1 Technical performance

The simulated system provides continuous service because the utility grid is available as a supplementary source and the model reports zero unmet electric load and zero capacity shortage. The PV system reduces the amount of grid energy required, particularly during daytime operation. The strong temporal overlap between campus charging demand and solar availability is favorable for direct PV utilization.

However, the reported 999,999 kW grid connection is effectively unconstrained. Consequently, the zero-unmet-load result demonstrates reliability under the modeled grid assumption rather than demonstrating performance under an actual campus feeder constraint. A practical study should replace this value with the campus transformer/feeder capacity and evaluate constrained-grid scenarios.

5.2 Battery-storage interpretation

The thesis specifies a 100 kWh LiFePO₄ BESS with a 20–80% SOC operating range and describes storage as a means of improving charging continuity, supporting low-solar periods and managing transient demand. At the same time, the reported base-case HOMER result pages emphasize PV production, grid purchases and converter/inverter outputs, and the thesis describes the grid as the primary mechanism for stable charging in the analyzed configuration.

Accordingly, this paper does not assign a numerical annual energy contribution or economic benefit to the BESS beyond the values explicitly reported. For publication-quality reproducibility, the revised model should report annual battery throughput, charge/discharge energy, SOC profile, equivalent cycles and the economic difference between PV+grid and PV+BESS+grid configurations.



5.3 Charging-power consistency

The supplied screenshot visibly reaches approximately 400–450 kW, this may indicate that the time-series load represents an aggregate campus electrical load rather than only the nominal EVCS rating.

5.4 Economic and environmental interpretation

The economic outputs indicate that the modeled hybrid configuration has a reported LCOE of \$0.1428/kWh and an annual operating cost of \$90,771.55. The independent simple-payback reconstruction closely reproduces the reported 5.95-year value. The environmental results show that grid electricity remains the dominant source and therefore remains the dominant contributor to the modeled emissions.

The thesis itself notes that economic feasibility is sensitive to PV cost, battery cost, maintenance cost and operational assumptions. It also identifies weather variability, EV behavior and lack of hardware validation as limitations. These limitations should be carried forward into the journal manuscript rather than presenting the simulation results as field measurements.

VI. LIMITATIONS AND REPRODUCIBILITY REQUIREMENTS

Observed limitation	Effect on interpretation	Required revision for a stronger journal version
Assumed campus charging profile	May not represent actual arrival/parking/charging behavior.	Use measured campus EV charging data.
999,999 kW grid connection	Makes grid supply effectively unconstrained.	Use actual campus feeder/transformer limit.
BESS contribution not quantified in reported results	Storage benefit cannot be independently verified.	Report BESS dispatch, SOC, throughput and economics.
100 kW charging envelope vs. >300 kW time-series peaks	Creates ambiguity in system scale.	Clarify load definition and charger aggregation.
Economic assumptions not fully exposed in result summary	Limits independent reproduction of NPC/LCOE.	Report lifetime, discount rate, replacement and tariff assumptions.
CO ₂ calculations use more than one basis	Can produce different avoided-emission values.	Define HOMER factor and counterfactual boundary.
Simulation-only study	No field validation.	Validate with measured or pilot data.

The thesis explicitly identifies simulation assumptions, weather variability, assumed EV behavior, economic uncertainty and the absence of hardware implementation as limitations. It also proposes future work involving AI/ML energy management, V2G, IoT monitoring, wireless charging, fast charging and experimental validation.

VII. CONCLUSION

A HOMER-based techno-economic assessment of a solar-powered EV charging station for campus use has been presented using the supplied thesis and HOMER simulation outputs as the primary case-study sources. The modeled architecture integrates 60 kW solar PV, a 70 kW conversion stage, a 100 kWh BESS concept, EV charging, utility-grid support and energy management.

The principal annual result is an EV charging load of 1,09,500 kWh/year out of total campus load of 884,852 kWh/year supplied by 115,588 kWh/year of solar PV and 774,118 kWh/year of grid purchases. The model reports zero unmet electric load and zero capacity shortage, with 12.5% w.r.t total campus load & 100% w.r.t EV charging load of annual renewable fraction and 93.2% maximum renewable penetration. The economic outputs are \$1,633,301 NPC, \$0.1428/kWh LCOE, \$90,771.55 annual operating cost, 16.78% reported ROI and 5.95-year reported payback. The HOMER emissions output is 489,243 kg CO₂/year, together with 2,121 kg SO₂/year and 1,037 kg NO_x/year.



The results support the technical usefulness of solar-assisted EV charging for campus applications under the modeled assumptions, while also demonstrating continued grid dependence at the annual level. For a stronger peer-review submission, the most important improvements are the use of measured campus charging data, realistic grid constraints, explicit BESS dispatch results, full economic assumptions, sensitivity analysis and a single clearly defined emissions baseline. These additions would improve reproducibility and strengthen the connection between the simulation study and practical campus deployment.

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