

Economic analysis of hybrid microgrid system – A case Study

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ABSTRACT

This study evaluates the technical and economic performance of a photovoltaic and diesel generator-based power system developed for a part of the Delhi-NCR campus. The system modelling and optimization were carried out using HOMER Software. The system was evaluated using technical, economic, and environmental parameters. These parameters included the initial system cost and investment recovery time. Annual electricity generation and the contribution of solar power to the total electricity supply were also considered. In addition, emissions released during system operation were assessed to evaluate the environmental performance of the system. Among the configurations analysed, the optimal system consisted of PV (89.7 kW), DG (100 kW) and BSS (335 kWh) operating under a cycle charging dispatch strategy.

Keywords: PV, DG, HOMER, Microgrid.

Nomenclature

PV	Photovoltaic
BSS	Battery storage system
WT	Wind Turbine
DG	Diesel Generator
NPC	Net present cost
LCOE	Levelized cost of energy
CRF	Capital recovery factor
HOMER	Hybrid optimization of multiple energy resources

INTRODUCTION

The growing use of distributed energy resources has increased the need for economic assessment of off-grid electrification system. The integration of renewable energy sources such as solar and wind also requires proper evaluation of the Levelized Cost of Energy to ensure reliable and cost-effective operation in remote areas. Several studies have used HOMER for the techno-economic analysis of hybrid renewable energy systems integrating photovoltaic arrays, wind turbines, battery storage systems, and diesel generators. The software evaluates different system configurations and identifies the optimal design based on Net Present Cost, operating cost, and system reliability (1).

In addition, economic parameters such as the Capital Recovery Factor and annual real interest rate are important for evaluating long-term project feasibility and lifecycle cost analysis. Sensitivity analysis is widely used to study the effects of fuel price variation, solar irradiance, and load demand uncertainty on system performance and economic stability. These analyses help identify suitable hybrid system configurations for rural and isolated regions where high initial investment remains a major challenge for renewable energy deployment (2).

Moreover, evaluation of NPC and LCOE provides a useful basis for comparing standalone renewable systems with conventional grid extension methods. This study further investigates the role of electrochemical energy storage technologies in isolated hybrid microgrid systems. Different battery technologies affect system reliability, replacement cost, lifecycle emissions, and overall economic performance. The study also examines the influence of geographical location and meteorological conditions on component sizing and hybrid system design, which is important for improving the performance of decentralized power systems (3).

In this research article, an academic building at Delhi-NCR campus was selected for techno-economic analysis. The coordinates of the site are 28.8377° N latitude and 77.5826° E longitude.



Figure 1: Location of Delhi-NCR campus

LITERATURE REVIEW

The literature review section presents a systematic discussion of existing studies, methodologies, findings, and research gaps relevant to the proposed research area.

Author	Year	Microgrid components	Grid type	Software	Location	Key finding	References
Hedra Saleeb	2025	PV, BSS, Hydrogen, Fuel cell	Grid	MATLAB / HOMER	Sohag University New campus Sohag AI Gadida city, Egypt	The optimized system reduced carbon emissions and provided 20–30% cost savings over 20 years.	(4)
D. Suganthi	2025	PV, BSS, WT, DG,	Grid	HOMER	Vellore Institute of Technology Chennai, Tamil Nadu, India	The achieved a drastic reduction in greenhouse gas emissions, reducing CO ₂ emissions from 2,756,885 kg/year to only 14,621 kg/year.	(5)
Musong L. Kathe	2024	PV, BSS	Grid	HOMER	Moi University, Eldoret, Kenya	The system achieved an LCOE of KSH 8.78/kWh and NPC of KSH 27.97 million.	(6)
Kayode Timothy Akindeji	2023	PV, WT, DG, BSS	Grid	HOMER	Howard College Campus, University of KwaZulu-Natal (UKZN), Durban, South Africa	The achieved annual utility bill savings of about R15.7 million, reduced CO ₂ emissions by 51%, provided a return on investment of 20–25%.	(7)
Mohammed Abdullah H. Alshehri	2023	PV, WT, BSS	Grid	HOMER	King Saud University Campus, Riyadh, Saudi Arabia	The system achieved more than 82% renewable energy penetration while	(8)

						reducing greenhouse gas emissions and operational costs compared to the existing diesel-grid system.	
Abdulrahman Alkassem	2022	PV, WT, BSS	Grid	HOMER	Islamic University of Madinah (IUM), Madinah, Saudi Arabia	All configurations significantly reduced CO ₂ , SO ₂ , and NO _x emissions while supporting Saudi Arabia's renewable energy integration goals.	(9)
Samson Dauda Yusuf	2022	PV, DG, BSS	Grid	HOMER/MATLAB	Nasarawa State University Keffi (NSUK), Nigeria	The optimized system achieved a Net Present Cost of \$2,499,296.31 and a Cost of Energy of \$0.05/kWh	(10)
Muhammad Shahzad Pansota	2021	PV, WT, DG, BSS	Grid	HOMER	University of Engineering and Technology (UET), Taxila, Punjab, Pakistan	Greenhouse gas emissions were reduced by 780.68 kg/day in summer and 730.46 kg/day in winter.	(11)
Hafiz Abdul Muqet	2021	PV, WT, Biomass, Fuel Cell, DG, BSS	Grid	MATLAB	Review of Multiple Universities Worldwide (Serbia, Italy, Singapore, USA, China, India, etc.)	The study highlighted that integrating renewable energy sources with battery storage and intelligent EMS improves reliability, sustainability, and economic performance.	(12)
Ahmad F. Tazay	2020	PV, WT, Fuel Cell, Hydrogen, BSS	Off Grid	MATLAB	Al Baha University, Saudi Arabia (KSA)	Achieved the minimum Net Present Cost of \$9,395,142 and Cost of Energy of \$0.289/kWh.	(13)

Methodology and Load site:

A power generation system using solar PV, a wind turbine, battery storage and a diesel generator is examined in this study. The system modelling and analysis are carried out using HOMER software. The objective of the study is to determine the optimal system configuration based on minimum Total Net Present Cost and Cost of Energy. The results obtained from HOMER are further validated using an optimization technique (14).

Net Present Cost:

$$NPC = \frac{C_{annual,total}}{CRF(i, N)} \quad (1)$$

$C_{annual,total}$ represents the total annual cost, i denotes the annual real interest, N represents the system lifetime and $CRF(i, N)$ denotes the capital factor (15).

Capital Recovery Factor:

$$CRF = \left[\frac{i(1+i)^N}{(1+i)^N - 1} \right] \quad (2)$$

i denotes the annual real interest, N represents the system lifetime.

Cost of Energy:

$$COE = \left\{ \frac{C_{annual,total}}{E} \right\} \quad (3)$$

E represents the primary load demand in kwh/year, $C_{annual,total}$ denotes the total annual cost in \$/year (15).

Load site:

The load assessment was performed for 15 classrooms located in a building at the SRM-IST Delhi-NCR campus. Each classroom includes LED lights, ceiling fans, an air conditioner, an LCD projector, a PA system consisting of microphones and speakers, a computer system, and electrical plug points. The major portion of the load demand occurs during daytime operating hours due to classroom activities. The average operating duration of each classroom is approximately 6 hours per day, resulting in a daily electricity requirement of about 398.8 kWh (16).

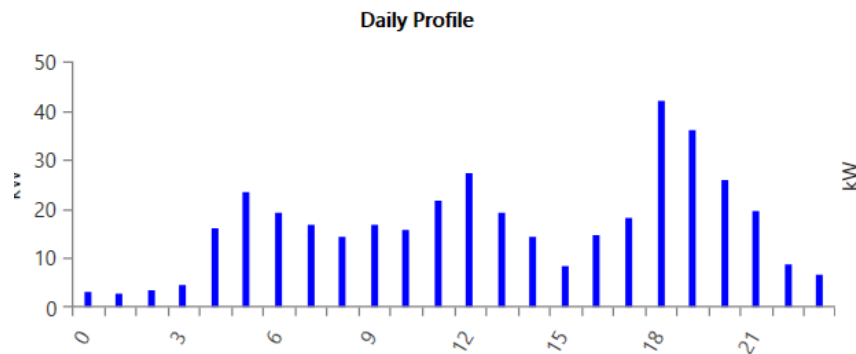


Figure 2: Daily load profile for 15 classrooms Delhi-NCR Campus.

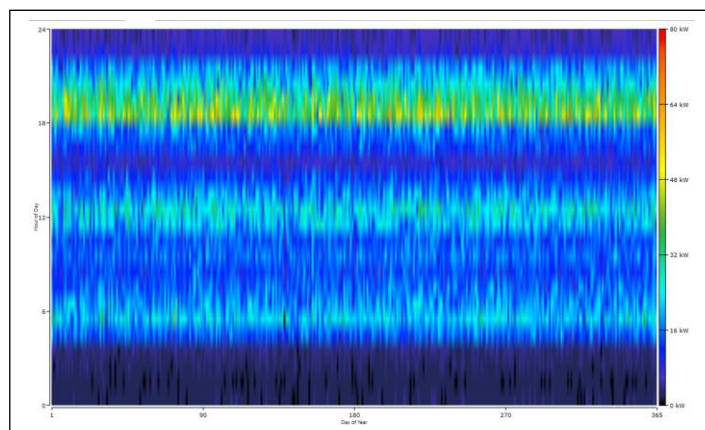


Figure 3: Annual load variation for 15 classrooms at Delhi-NCR Campus.

Components of Renewable Sources:

PV: A Generic Flat Plate PV system with a rated capacity of 1 kW is considered in this study. The capital cost and replacement cost of the PV system are taken as \$2500/kW each. The operation and maintenance cost assumed to be \$10/year. These parameters are used in the HOMER-based techno-economic analysis.

Battery Storage System: A battery storage unit with a nominal voltage of 6 V and a nominal capacity of 1 kWh is used in the proposed system. The capital cost of the battery is considered as \$550/unit, while the replacement cost is also

taken as \$550/unit. The operation and maintenance cost assumed to be \$10/year. These specifications are included in the HOMER simulation for techno-economic evaluation

Diesel Generator: A diesel generator with a rated capacity of 100 kW is included in the hybrid energy system. The capital cost of the generator is considered as \$40,000, and the replacement cost is also taken as \$40,000. The fuel cost is assumed to be \$1.00/L. The operation and maintenance cost of the generator is calculated based on operating hours. These parameters are used in the HOMER simulation for techno-economic analysis of the system.

RESULTS AND SIMULATION

HOMER software was used to simulate an off-grid hybrid power system consisting of a PV, Diesel Generator, and Battery storage system. The proposed configuration was analysed to supply the selected load. The simulation results are presented in Table 1. The system performance was evaluated using techno-economic parameters such as Net Present Cost, Cost of Energy, renewable energy fraction, annual fuel consumption, pollutant emissions, and electrical energy generation. The analysis was carried out to identify a technically and economically suitable system configuration. In addition, the effect of variation in PV capacity and battery storage size was examined through sensitivity analysis. The hourly energy balance of the hybrid system was also analysed for a 24-hour operating period.

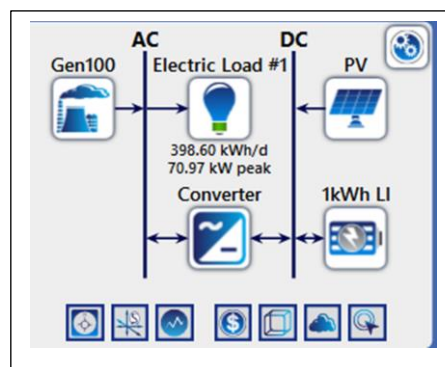


Figure 4: System Design.

The optimization results of the proposed hybrid system are presented in Table 1. The table includes the optimal configuration obtained from HOMER simulation based on techno-economic analysis.

Table 1: Optimization results obtained using HOMER

Architecture				Cost		
PV (kw)	DG (kw)	BSS (kwh)	Converter (kw)	NPC (\$)	LCOE (\$/kwh)	Operating cost (\$/year)
89.7	100	335	49.1	\$762,777	\$0.406	\$23,172
-	100	130	44.6	\$1.07M	\$0.569	\$73,131
328	-	644	91.4	\$1.46M	\$0.777	\$19,892
-	100	-	-	\$1.63M	\$0.867	\$123,058
2.08	100	-	0.557	\$1.64M	\$0.870	\$123,034

Cases Based analysis of HOMER:

Case 1: The optimal configuration lowest NPC and COE all the considered cases. The system consists of 89.7 kW PV, 100 kW diesel generator, 335 kWh battery storage system, and a 49.1 kW converter. The integration of the PV system reduces diesel fuel consumption and operating cost. In addition, the use of solar PV increases the renewable energy contribution and reduces pollutant emissions, making the system more environmentally sustainable. Therefore, this configuration is considered technically and economically suitable for the selected load demand.

Case 2: A higher Net Present Cost and operating cost compared to Case 1 due to the absence of the PV system. The configuration mainly depends on the 100kW diesel generator for power generation. As a result, fuel consumption

increases, which leads to higher operating cost and increased pollutant emissions. Continuous operation of the diesel generator also increases environmental pollution due to carbon and other harmful gas emissions.

Case 3: An environmentally friendly configuration because it uses a large PV system and battery storage without a diesel generator. The absence of diesel fuel reduces pollutant emissions and increases renewable energy utilization. However, the system has a high Net Present Cost and Levelized Cost of Energy due to the large PV and battery capacities. Therefore, this configuration is less economically sustainable for the selected load demand.

Case 4: The only a 100kW diesel generator without the integration of PV or battery storage systems. Since the entire load demand is supplied by the diesel generator, the system shows high operating cost, Net Present Cost and Levelized Cost of Energy. Continuous use of fossil fuel also increases fuel consumption and pollutant emissions, resulting in higher environmental impact. Therefore, this configuration is less sustainable from both economic and environmental perspectives.

Case 5: Includes a 100kW diesel generator with a very small PV capacity and does not include a battery storage system. Due to the low contribution from PV generation, the diesel generator supplies most of the electricity required by the system. As a result, the system has high operating cost, Net Present Cost and fuel consumption. In addition, the absence of battery storage reduces backup support during variations in load demand and renewable generation. Continuous dependence on fossil fuel also increases environmental pollution.

Table 2: Components wise cost summary of HOMER optimization system combination

Component	Capital (\$)	Replacement (\$)	O&M (\$)	Fuel (\$)	Salvage (\$)	Total (\$)
DG	\$40,000	\$17,258.67	\$26,372.13	\$122,131.25	\$2,874.69	\$202,887.36
Battery	\$184,250	\$84,298.65	\$43,307.18	\$0	\$7,614.60	\$304,241.23
PV	\$224,230.04	\$0	\$11,594.95	\$0	\$0	\$235,824.99
Converter	\$14,745	\$6255.92	\$0	\$0	\$1177.43	\$19,823.49
System	\$463,225.04	\$107,813.24	\$81,274.26	\$122,131.25	\$11,666.72	\$762,777.07

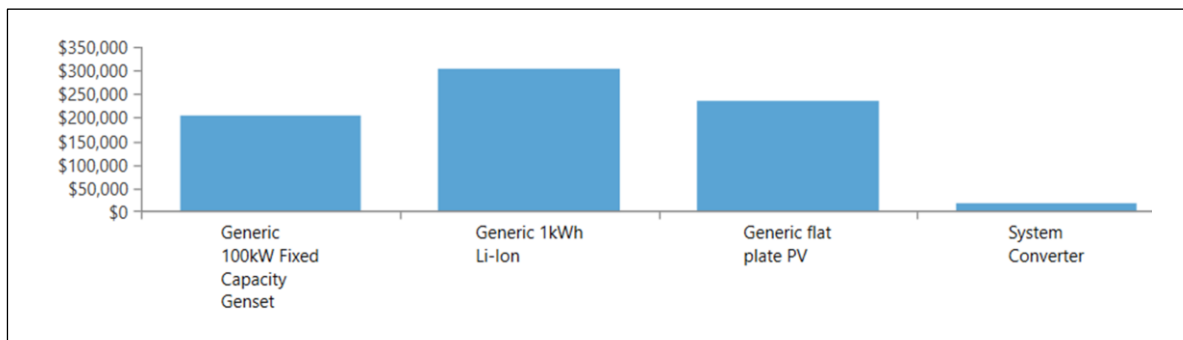


Figure 5: Cost summary of Homer configuration.

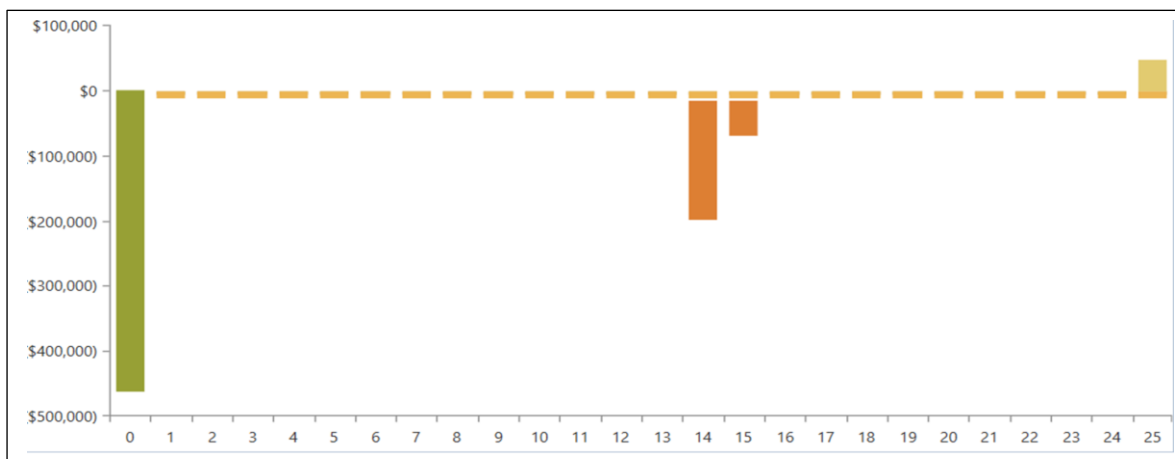


Figure 6: Cash flow of Homer configuration

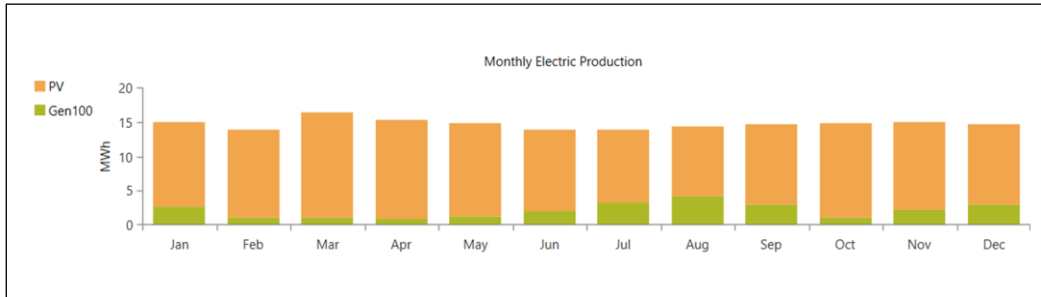


Figure 7: Monthly electric production of Homer configuration.

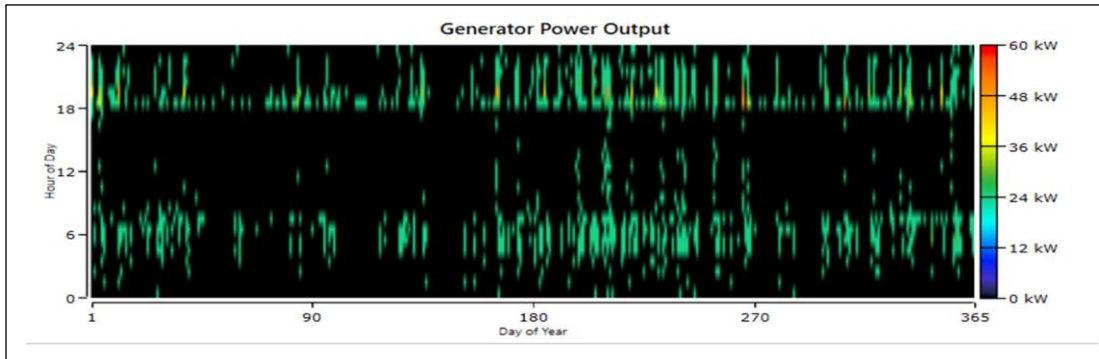


Figure 8: Power output From Diesel Generator in a year.

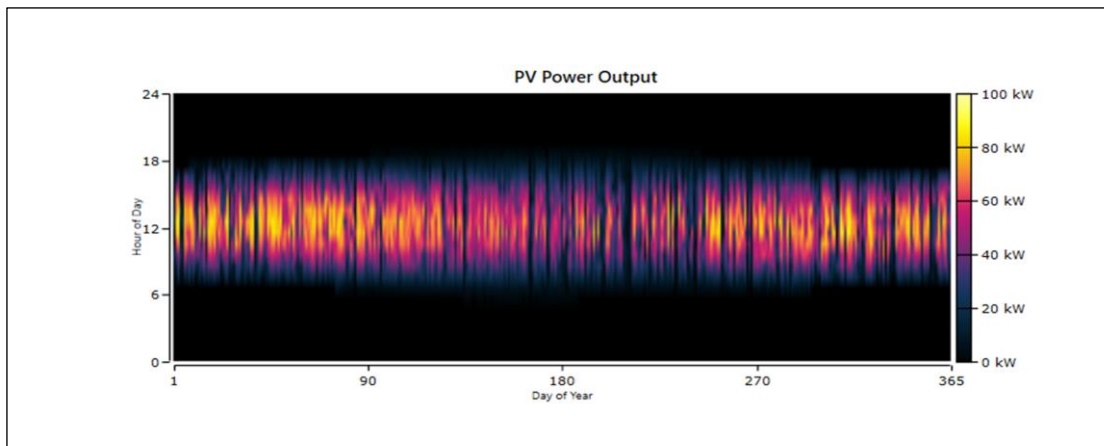


Figure 9: Power output from PV in a year.

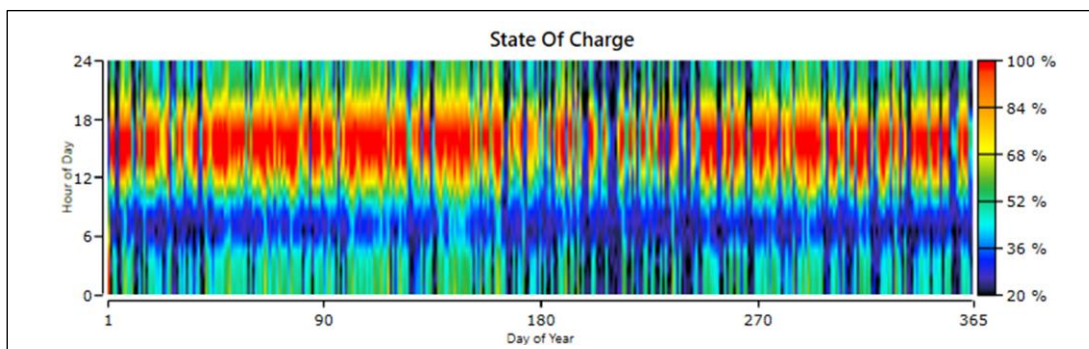


Figure 10: Battery state of charge in a year.

Sensitivity Analysis:

A sensitivity study was carried out to examine how different system inputs affect the technical and economic performance of the hybrid energy system. This approach assists in identifying how changes in key variables affect the overall system operation, reliability, and economic feasibility.

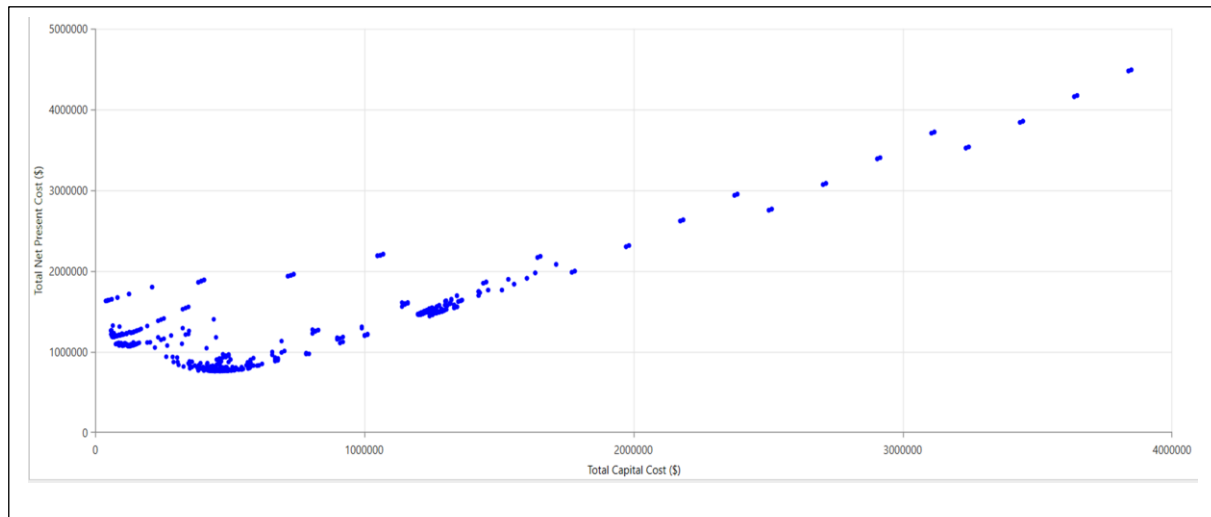


Figure 11: Optimization Plot of NPC and total capital cost.

CONCLUSION

This study aims to determine an optimal electricity generation solution for a section of the Delhi-NCR campus. The primary objectives were to minimize the cost of energy in comparison with the utility grid tariff and to reduce atmospheric pollutant emissions. The most suitable configuration consisted of SPP (89.7 kW), DG (100 kW), and BSS (335 kWh), with the system operating in cycle charging mode. The system evaluation was carried out based on several techno-economic parameters, including net present cost, cost of energy and operating cost. The obtained values were \$762,777 for NPC, \$0.406/kWh for COE and \$23,172/year for operating cost.

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