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Sustainability Assessment of Hybrid Powered Electric Vehicle Charging Stations

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Abstract *– This paper presents a electric vehicles (EVs) continues to rise, the sustainability of their charging infrastructure becomes crucial. This paper presents a comprehensive assessment of hybrid-powered EV charging stations, integrating renewable energy sources with conventional grid power. The primary objectives include evaluating the environmental impact, economic viability, and social implications of such hybrid systems.*

The proposed methodology involves a multi-faceted approach, combining life cycle assessments, economic modeling, and stakeholder analysis. Environmental impacts, including carbon emissions and resource depletion, are quantified to assess the ecological footprint of hybrid charging stations compared to traditional counterparts. Economic models incorporate initial investment costs, operational expenses, and potential revenue streams to determine the financial sustainability of these hybrid solutions.

The social dimensions, considering factors such as accessibility, community engagement, and job creation associated with hybrid EV charging stations. The findings aim to guide policymakers, industry stakeholders, and urban planners in making informed decisions towards a more sustainable and resilient future for EV infrastructure.
Keywords: Hybrid Powered, PV-grid charging station, Electric vehicle charging, smart grid, Vehicle to grid, Bidirectional DC converter, Energy storage unit.

I. INTRODUCTION

The swift expansion of electric vehicles (EVs) has instigated a transformative change in the transportation sector, guiding it towards a future characterized by sustainability and environmental friendliness. As the EV market expands, the demand for efficient and eco-friendly charging infrastructure becomes increasingly crucial. In response to this need, hybrid powered electric vehicle charging stations have emerged as a promising solution, integrating renewable energy sources with traditional grid power to enhance sustainability.

Hybrid powered charging stations combine various energy inputs, such as solar, wind, and grid electricity, to provide a reliable and resilient charging infrastructure for electric vehicles. This innovative approach aims to address both the rising energy demand for EV charging and the imperative to reduce greenhouse gas emissions associated with transportation.

A. Varieties of Electric Vehicles and Charging Stations for Electric Vehicles (EVCS)

The electric vehicles (EVs) have garnered significant interest as a viable alternative technology within the realm of modern transportation. These electric vehicles (EVs) can be classified into three main types, distinguished by the origin of the electricity used to power the vehicle:

(a) Electric hybrid vehicles (HEVs)
(b) Electric plug-in vehicles (PEVs)
(c) Electric fuel cell vehicles (FCEVs).

Hybrid Electric Vehicles (HEVs) incorporate a dual propulsion system, comprising an electric propulsion system and an internal combustion engine. This integration aims to enhance fuel efficiency, reduce emissions, extend the driving range, and surpass the performance of conventional internal combustion engine vehicles.

Plug-in Electric Vehicles (PEVs) encompass both Battery Electric Vehicles (BEV) and Plug-in Hybrid Electric Vehicles (PHEV). A BEV relies solely on an electric propulsion system, drawing 100% of its power from rechargeable batteries. In contrast, a PHEV predominantly relies on an electric propulsion system powered by a battery, supplemented by a gasoline engine that serves as a backup in the event of complete battery discharge

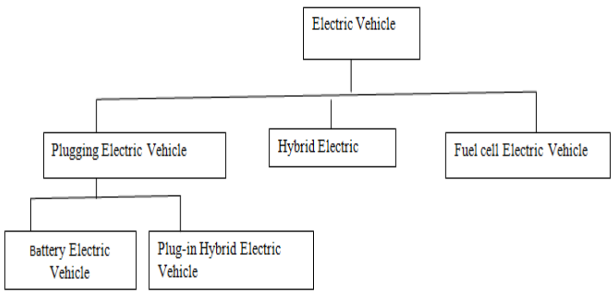

Figure 1 Varieties of electric vehicles

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The Electric Vehicle Charging Station (EVCS) serves as a vital component in the electric vehicle (EV) charging infrastructure, often referred to as Electric Vehicle Supply Equipment (EVSE). Its fundamental role is to furnish electriscal energy to EVs for charging, drawing from a range of energy sources. The classification of EVCS depends on various factors, such as the power supply type, integration with the power grid, charging power levels, infrastructure type, mobility considerations, and the direction of power flow. The subsequent delineation of EV charging stations is elaborated based on these diverse factors

II . ELECTRIC VEHICLE (EV) CHARGING TECHNOLOGY

A Building a dependable and efficient charging station This analysis provides a comprehensive overview of diverse power levels, associated costs, and the advantages and disadvantages of different Electric Vehicle (EV) charging technologies. The charging duration for an Electric Vehicle is primarily influenced by the charging level of the battery. Other crucial factors include the EV battery's capacity to handle high charging rates, the charging cable, and the Electric Vehicle Supply Equipment (EVSE). The EVSE serves as the infrastructure facilitating the delivery of electrical energy to the charger, also referred to as an electric recharging unit. It encompasses essential components such as charging cords, ports, connectors, and interfaces for efficient battery charging. International standards, including IEC 61851, Electric Power Research Institute (EPRI), Society of Automotive Engineers (SAE), and International Electro-Technical Commission (IEC), categorize various charging modes or levels, including Alternating Current (AC) - Level 1, Level 2, Level 3, and Direct Current (DC) Level 4

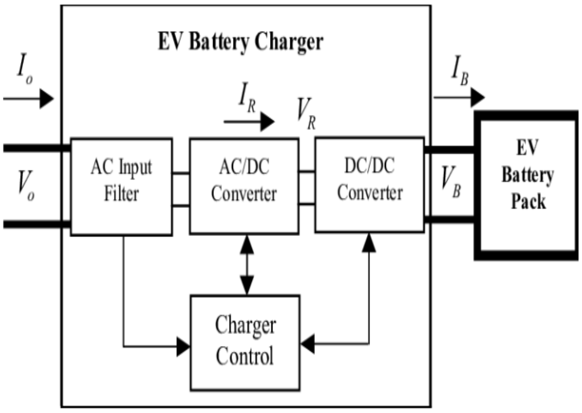

Fig 2 Block diagram of a common battery charger

According to the EPRI report, Electric Vehicle (EV) users express a preference for charging their vehicles upon reaching home, with a particular inclination towards night-time charging. Consequently, AC Level 1 (slow) charging is the favored method for home EV charging, often referred to as overnight or residential charging. The equipment used for slow charging is compatible with standard wall outlets typically found in homes. In Level 1 charging mode, the vehicle's onboard charger converts electric power from Alternating Current (AC) to Direct Current (DC). It is crucial to acknowledge that this power conversion process may vary across regions or countries due to differences in standards and frequencies

III. METHOD

The flowchart in Figure 3 illustrates the process for Electric Vehicles (EVs) based on renewable energies. This study adopts a segmented methodology, utilizing data from various research articles for specific purposes. Estimations for daily and seasonal loads are made to meet the demand for EVs, with the charging requirements varying based on the type of EV utilized. The proposed system in this paper is classified into economic, environmental, and technical parameters.
Component selection is influenced by market price and availability, while technical parameters consider factors such as electricity demand, power generation from renewable sources like solar and biogas energy, digester size, rating of biogas generators, and more. Economic parameters encompass the Net Present Cost (NPC), Cost of Energy (COE), and Profitability Index (PI). The analysis employs HOMER Pro (JMK Research & Analytics, 2021), utilizing specific equations to evaluate these parameters.

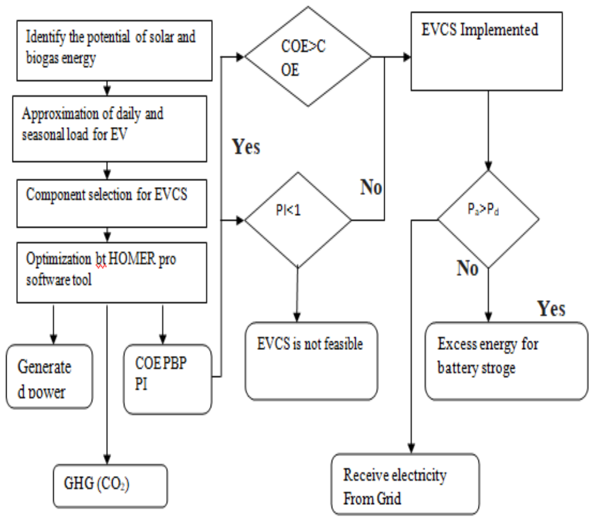

FIG. 3 : Flowchart depicting the Proposed System

IV. RESULT

A. Long-Term Specific Energy Consumption

In the initial phase of identifying influencing factors, an analysis of long-term energy consumption values is conducted. Even with the deployment of all-electric vehicles (EVs) on consistent routes, notable fluctuations in energy consumption over time are apparent for the two types of EVs used (Fig. 4). Notably, discernible variations in the specific energy consumption of e-Wolf

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Delta 2 vehicles are observed depending on routes and seasons.. Route composition, with inter-urban and motorway segments, contributes to the differences, with Route 4, primarily a motorway, exhibiting the highest average speed (60 km/h) and, consequently, the highest specific energy consumption.

Identifying the factors causing fluctuations is challenging. Some variations are attributed to changes in commuting routes, influenced by a single worker's holiday, affecting specific energy consumption. Fluctuations are also correlated with variations in outside temperature. Between November 2014 and March 2015, there is an observed increase in specific energy consumption of approximately 20 Wh/km for most e-Wolf Delta 2 vehicles. This rise is likely influenced by a combination of battery chemistry and battery management design, as lower temperatures tend to reduce battery efficiency.

Despite various contributing factors, the data emphasizes that cabin heating, which draws energy from the battery, exerts the most significant influence. A peak value of nearly 4 kW for cabin heating power drawn from the battery underscores its substantial impact on specific energy consumption, even at a relatively high average speed. At the recorded average speed of approximately 70 km/h for business trips, the entire heating power of 4 kW results in an additional specific energy consumption of 57 Wh/km, constituting a 33% increase over the NEDC. Under such conditions, short-term test measurements on urban routes revealed specific energy consumption values reaching up to 280 Wh/km

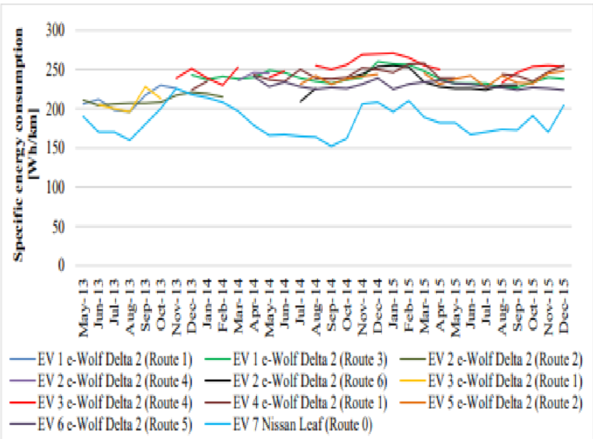


Figure 4: Monthly average specific energy consumption data recorded for the RheinMobil

B. Influence of Drag and Auxiliary Components on Specific Energy Consumption

The results obtained from the energy consumption simulation model, designed for both EV types utilizing averaged empirical driving profiles with proportionally varied speed values, vividly highlight the contrasting impacts of auxiliaries and drag concerning average speed on specific energy consumption. Figure 5.2 depicts the total specific energy consumption drawn from the battery in relation to average speed for both EV types and two levels of auxiliary demand—1.1 kW as the average and 4 kW as the maximum, aligning with recorded values

Maintaining the auxiliaries' power demand at a constant 1.1 kW reveals notably similar energy consumption at low average speeds for both EV types. However, as the average speed increases, the disparity between the two curves becomes more pronounced. At higher average speeds, the difference between the various auxiliary demand levels diminishes. The progression of the curves illustrates the evolving influence of auxiliaries and drag at different speed levels.

Under these driving conditions, with a consistent use of 1.1 kW auxiliaries, the minimum specific energy consumption occurs at 22 km/h for the Delta 2 and 28 km/h for the Leaf. When the auxiliaries' power demand reaches the maximum of 4 kW, the minimum specific energy consumption occurs at 38 km/h for the Delta 2 and 42 km/h for the Leaf, respectively

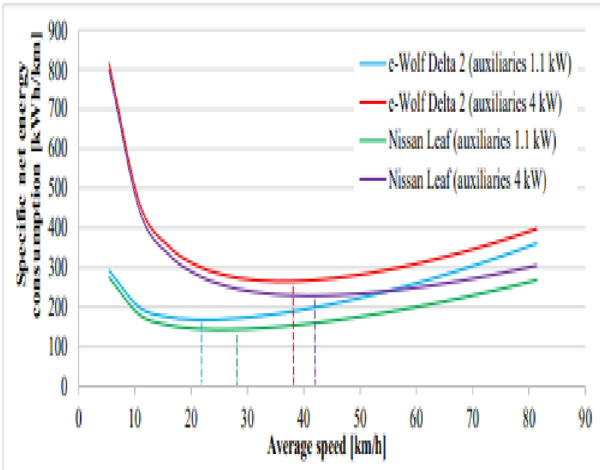


Figure 5: Energy consumption model for e-Wolf Delta 2 and Nissan Leaf based on averaged empirical driving profiles.

C. Impact of Speed Variability on Energy Consumption

The empirical observations highlight that the distribution of speed values significantly impacts specific energy consumption, underscoring its importance. Illustrated in Figure 5.3 is the relationship between specific energy consumption and recuperation concerning the standard deviation of speed values for an individual trip, considering its correlation with average speed. Even within the constrained range of average speed values (56 to 73 km/h), the consistent nature of inter-urban and motorway driving profiles facilitates the identification of clear correlations.

Both specific energy consumption and recuperation witness an increase with a higher standard deviation of speed values. However, the upsurge in recuperation does not completely counterbalance the increase, which is understandable due to efficiency rates, imperfect driving conditions, and the quadratic increase in losses associated with drag at higher speeds. Consequently, the specific net energy consumption rises with a higher speed variance. Additionally, the data suggests that a higher average speed corresponds to a reduced standard deviation of speed values for a single trip. This interpretation requires caution as the EV followed a fixed route, eliminating changes in the route profile as a contributing factor, but may be influenced by traffic density or driving style

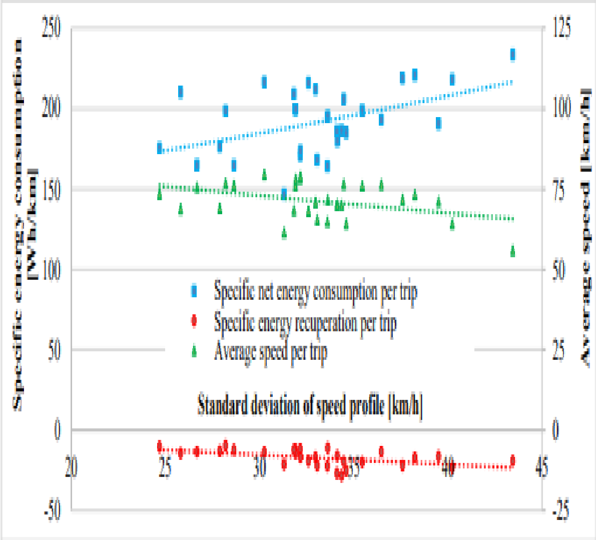
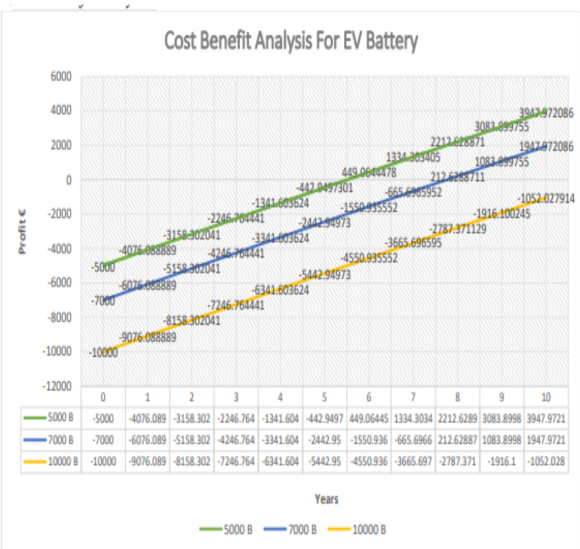


Figure 6: Observed impacts of speed variability on specific energy consumption and recuperation for the Nissan Leaf

Cost Benefit analysis



	0	1	2	3	4	5	6	7	8	9	10
5000 B	-5000	-4076.089	-3158.302	-2246.764	-1341.604	-442.9497	449.06445	1334.3034	2212.6289	3083.8998	3947.9721
7000 B	-7000	-6076.089	-5158.302	-4246.764	-3341.604	-2442.95	-1550.936	-665.6966	212.62887	1083.8998	1947.9721
10000 B	-10000	-9076.089	-8158.302	-7246.764	-6341.604	-5442.95	-4550.936	-3665.697	-2787.371	-1916.1	-1052.028

Figure 7. Cost Benefit Analysis for Different 40 Kw Battery Prices

Figure 7 presents the cost-benefit analysis for the acquisition of a 40 kW Battery Electric Vehicle (BEV) powered by wind energy, considering a degradation factor of 2% per year, for an annual drive of 20,000 km over a period of 10 years. The graph indicates that with a battery price of 5,000 €, the vehicle begins to yield a profit after the 5th year. In the case of a 7,000 € battery price, the car starts generating benefits after the 7th year. However, with a 12,000 € battery price, the vehicle does not generate any benefits even after 10 years of utilizing the car for a yearly drive of 20,000 km

V. Conclusion

This paper has focused on The sustainability assessment of hybrid-powered electric vehicle (EV) charging stations reveals a multifaceted perspective on the environmental, economic, and social aspects of these infrastructure projects. This assessment encompasses the integration of renewable energy sources, energy efficiency, economic viability, and the overall impact on the community

The sustainability assessment of hybrid-powered electric vehicle charging stations underscores the importance of a holistic approach, considering environmental, economic, and social factors. A successful charging station should not only provide a clean and efficient energy source but should also contribute positively to the community and align with broader sustainability goals. Continuous monitoring, adaptation to evolving technologies, and community involvement are key elements for ensuring the long-term success and positive impact of these infrastructure projects. PV-EV chargers incorporating V2G technology are anticipated to attract heightened attention and increased investments from both grid operators and car manufacturers in the future. In conclusion, the structure of photovoltaic charging systems is evolving into a more intricate framework with multiple integrated functions, necessitating intelligent controls for each component and real-time management for the entire station.

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