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Eco Friendly Power Source for Electric Vehicles Charging: A Hybrid Approach

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Abstract *– This paper presents a The swift expansion of electric vehicles (EVs) has generated an urgent demand for environmentally sustainable charging solutions. This summary examines a hybrid strategy for powering electric vehicle charging stations, incorporating various renewable energy sources to reduce ecological footprint. Solar panels capture energy from the sun, and wind turbines harness wind energy, collectively contributing to a clean and eco-friendly power source. Grid power acts as a backup, supplementing renewable sources during periods of low generation or high demand.*

The proposed methodology involves Smart energy management algorithms play a pivotal role in dynamically optimizing the energy mix based on real-time data, such as weather conditions, energy demand, and grid availability. These algorithms prioritize renewable sources in favorable conditions and seamlessly transition to grid power when necessary, ensuring a continuous and stable charging infrastructure.

The integration of energy storage systems, such as advanced batteries, further enhances the reliability of the hybrid system. Excess energy generated during optimal conditions can be stored for later use, addressing the intermittency of renewable sources and providing a consistent power supply for EV charging.
This hybrid approach not only reduces the carbon footprint associated with EV charging but also contributes to grid stability by intelligently managing the variability of renewable energy sources. By combining solar, wind, and grid power, the proposed system aims to create a sustainable and environmentally friendly solution to meet the growing demand for electric vehicle charging infrastructure. This research represents a significant advancement toward establishing a cleaner and more resilient energy ecosystem, supporting the widespread adoption of electric vehicles
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Keywords: Eco Friendly Power Source, Electric Vehicles, Charging, Hybrid Approach, Grid-To-Meter Energy Efficiency, Hybrid Dynamical System.

I. INTRODUCTION

The global shift towards sustainable and eco-friendly transportation has led to a significant increase in the acceptance of electric vehicles (EVs). With the increasing demand for EVs, there is a crucial requirement for charging solutions that are both efficient and environmentally responsible. Traditional power sources for EV charging, often reliant on fossil fuels, pose challenges in achieving a truly green and sustainable future.

A hybrid approach to electric vehicle charging emerges as a promising solution. This approach integrates multiple eco-friendly power sources, synergizing their strengths to create a resilient and efficient charging infrastructure.

The hybrid approach aims to enhance energy efficiency, reduce environmental footprint, and enhance the overall dependability of electric vehicle (EV) charging networks.

A.Charging Structure Design

The fundamental goal of scrutinizing and assessing the design of the Electric Vehicle (EV) charging system is to establish a reliable and efficient charging station. This station is designed to meet the increasing power demands of EVs at the chosen location and possesses the capability to either contribute power back to the electricity grid or use it for conventional on-site loads. However, a crucial consideration is that the generation of Renewable Energy Sources (RES) relies on various factors, including installation location, seasonal variations, daily weather changes, power grid stability concerns (such as power quality and voltage variations), and storage system capacity. Consequently, this thesis undertakes the implementation of an integrated system design for a hybrid Photovoltaic (PV)/grid/storage system tailored for EV charging.

The first-level control and online energy management focus on maximizing PV power utilization, enhancing charging system capacities, minimizing electricity purchase costs from the grid, and mitigating grid stress arising from simultaneous recharging of numerous EVs. By integrating the electricity grid with PV and ESS utilization, coupled with the implementation of a relevant control and Energy Management System (EMS), a positive impact on the EV charging process is anticipated.

II . EV CHARGING POWER CONVERSION: TOPOLOGIES

Electric Vehicle (EV) chargers come in two configurations: off-board and on-board, as illustrated in Figure 1.1. Generally, the use of off-board chargers has the potential to decrease both the overall cost and the size of the vehicle. A recent trend involves utilizing AC grids to provide power to EVs equipped with integrated chargers [17]

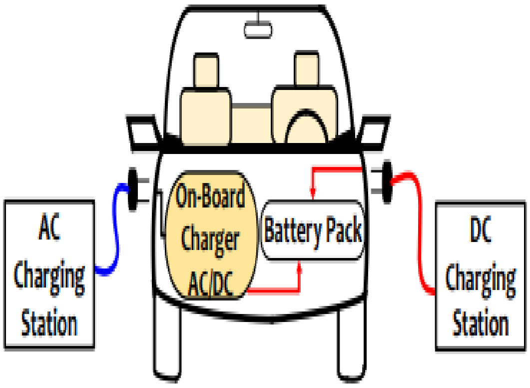
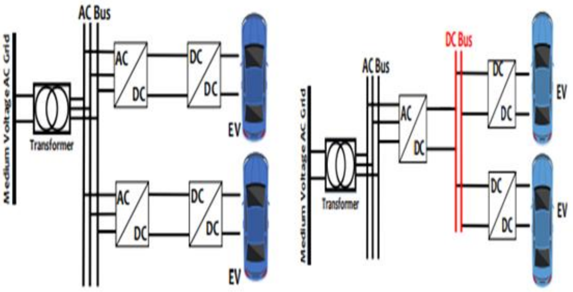


Fig. 1: Configurations of EV Chargers: On board versus Off-board

Incorporating on-board fast chargers for Electric Vehicles (EVs) poses challenges attributed to the increased cost of essential electronic components required for energy conversion. These costs contribute to an overall escalation in the expenses associated with EVs. The limitations of on-board chargers in facilitating rapid EV charging arise from the substantial costs of power electronics embedded within the EV, necessitating an augmentation in the charger capacity within the vehicle. To address the demand for rapid Electric Vehicle (EV) charging, high-power off-board chargers, capable of delivering high DC power, are employed. In these off-board chargers, each AC/DC power conversion is executed through an independent inverter, requiring increased converter power to ensure swift vehicle charging

Numerous research studies have leveraged acquired insights to design effective and dependable EV charging systems at charging stations. This exploration has led to the concept of a public facility equipped with high-power off-board chargers, functioning akin to a fuel station for EVs by providing direct current for rapid recharging.

Within the architecture of a charging station connected to the grid, two options—AC and DC—are under consideration. The first architecture employs the secondary side of the step-down transformer as a shared AC bus, with each load connected through independent AC/DC stages. The second architecture utilizes a single AC/DC stage to supply a common DC bus service for the system load. The use of a shared AC bus is illustrated in Figure 1.2(a b), where each charging unit has a distinct rectifier linked to a common AC coupling point. However, this configuration may result in undesirable harmonic effects on the power grid, especially when multiple charging units with independent rectifiers are involved



(a) Charging units for Electric Vehicles (EVs) using a Shared AC Bus. (b) Charging units for Electric Vehicles (EVs) using a Shared DC Bus.

Fig. 2: Charging station configurations utilizing a shared bus system

III. METHOD

A sustainable strategy for powering electric vehicle (EV) charging stations often involves integrating various renewable energy sources and energy storage systems in a hybrid approach to enhance efficiency and reliability.

A. Solar Power

- Solar Panels: Install solar panels in charging stations or nearby areas to harness energy from the sun.
- Solar Tracking Systems: Implement tracking systems that follow the sun's movement to maximize energy capture.

Solar power is an eco-friendly energy source that harnesses the sun's energy to generate electricity or heat. This type of energy is deemed sustainable and environmentally friendly as it depends on the sun, an abundant and limitless resource.. Solar power can be harnessed through various technologies, with the two primary methods being photovoltaic (PV) systems and solar thermal systems.

Photovoltaic (PV) Systems:

Photovoltaic (PV) systems directly transform sunlight into electricity using solar cells. These cells, commonly made from semiconductor materials such as silicon, generate an electric current when exposed to sunlight. Solar panels, consisting of interconnected solar cells, are frequently deployed on rooftops or within solar farms to capture sunlight and transform it into usable electricity

Fig 3 Solar power

B. Wind Power

Wind Turbines: Implement small-scale wind turbines to capture wind energy, particularly in areas with steady wind patterns.
Vertical Axis Wind Turbines (VAWT): VAWTs may be better suited for urban environments and are less influenced by shifts in wind direction.

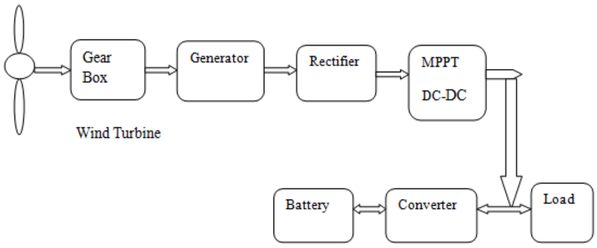


Fig 4 Wind Power

Wind power is an eco-friendly energy source that captures the kinetic energy of the wind to generate electricity. This energy form has been harnessed for centuries, starting with traditional windmills used for pumping water or grinding grain, and evolving into modern wind turbines that produce electricity

C. Energy Storage

Battery Storage: Utilize energy storage systems, specifically batteries, to store excess energy generated during peak production times and release it during periods of high demand.
Vehicle-to-Grid (V2G): Enable Electric Vehicles (EVs) to contribute excess stored energy back into the grid as needed..

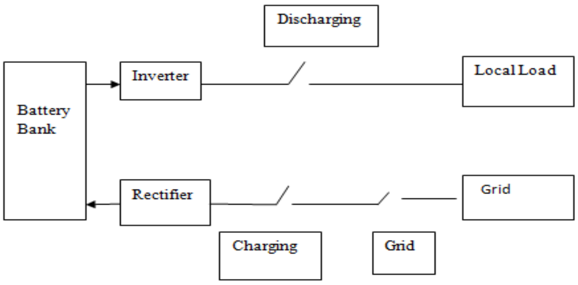


Fig 5 Block Diagram of the designed Energy Storage

Energy storage encompasses the capture and retention of energy for later use, playing a crucial role in the modern energy landscape. It addresses the intermittent nature of renewable energy sources, manages peak demand, and enhances grid reliability. Diverse technologies exist for energy storage, each with distinct advantages and drawbacks

IV. RESULT

Vehicles are inherently crafted for efficient terrestrial movement, displacing tropospheric air, and overcoming surface friction. To establish a fundamental understanding of the physical characteristics and energy requirements linked to the longitudinal motion of cars, a model has been utilized to evaluate these properties under realistic driving conditions. Originating from the Department of Industrial Electric Engineering and Automation (IEA), Faculty of Engineering (LTH), Lund University, this model is grounded in solving differential equations using Matlab and Simulink. The research in this thesis has introduced further improvements to the model, striving for more sophisticated and significant outcomes.

A. The Model

The model, illustrated in Figure 6, is tailored for Matlab Simulink and encompasses a comprehensive range of physical attributes pertinent to four-wheeled vehicles. It can accommodate variations from compact cars to heavy trucks by adjusting the corresponding input parameters. The primary application of this model is the evaluation of the longitudinal behavior of vehicles across standardized drive cycles. Key physical characteristics, including weight, air drag, roll drag, and engine and gearbox specifications, can be easily configured using initialization scripts. These scripts facilitate batch simulations, allowing for a direct comparison of results among different vehicles and drive cycles. Each sub-model represents distinct physical components such as the engine, brakes, gearbox, road, driver, etc. The model is structured around fundamental physical laws, ensuring consistency in units of force, mass, distance, torque, and their derivatives such as power, speed, and energy concerning time.

B. Drive Cycles

To simulate an authentic driving pattern within real traffic scenarios, two distinct drive cycles are utilized.

The New European Drive Cycle (NEDC, depicted in Figure 6) mirrors urban driving conditions and includes a brief segment of highway driving . On the other hand, the US06 drive cycle (illustrated in figure 7) emulates more rigorous highway driving conditions

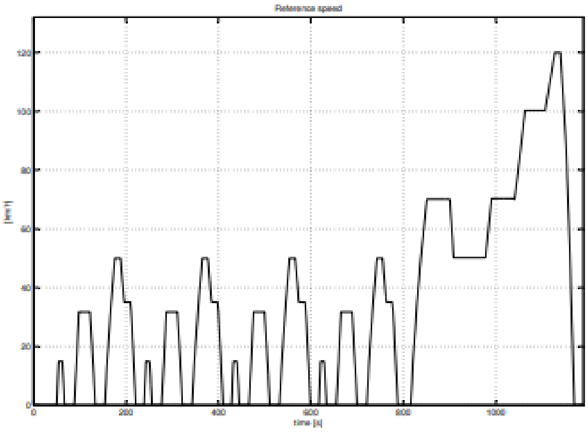


Figure 6: New European Drive Cycle (NEDC)

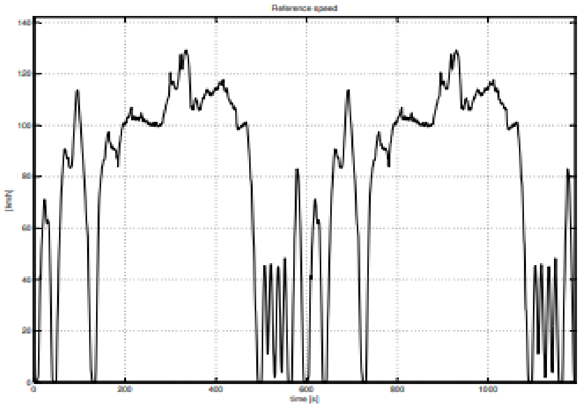


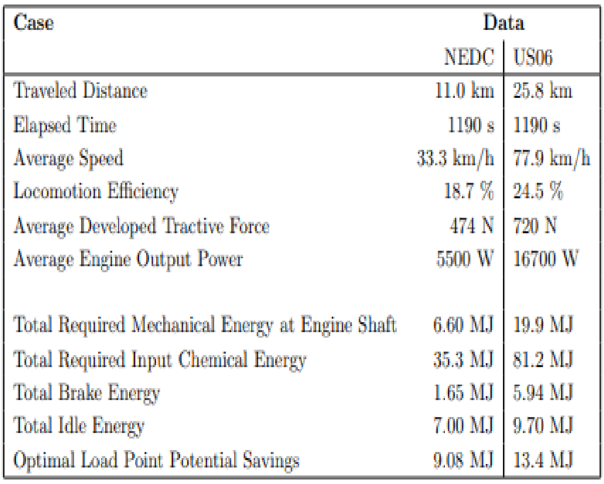
Figure 7: US06 Drive Cycle

C. Results

Four primary cases were thoroughly evaluated, with meticulous monitoring of both the mechanical energy at the drive shaft and the chemical (fuel) energy supplied to the combustion engine for each of the two drive cycles

Mechanical Energy

The scrutiny of mechanical energy before transmission is particularly intriguing, as it remains unaffected by the specific engine chosen for the vehicle, as long as the engine possesses sufficient strength to meet the power and torque demands of the drive cycle



Case	Data	
	NEDC	US06
Traveled Distance	11.0 km	25.8 km
Elapsed Time	1190 s	1190 s
Average Speed	33.3 km/h	77.9 km/h
Locomotion Efficiency	18.7 %	24.5 %
Average Developed Tractive Force	474 N	720 N
Average Engine Output Power	5500 W	16700 W
Total Required Mechanical Energy at Engine Shaft	6.60 MJ	19.9 MJ
Total Required Input Chemical Energy	35.3 MJ	81.2 MJ
Total Brake Energy	1.65 MJ	5.94 MJ
Total Idle Energy	7.00 MJ	9.70 MJ
Optimal Load Point Potential Savings	9.08 MJ	13.4 MJ

D. Price Trends and Experience Curves

The average cost of electric cars sold in Germany has experienced a significant 63% reduction, dropping from 1090 ± 560 EUR2015/kW in 2010 to 400 ± 220 EUR2015/kW in 2016. Similarly, the mean price of plug-in hybrids has decreased by 24%, transitioning from 330 ± 10 EUR2015/kW in 2011 to 250 ± 60 EUR2015/kW in 2016. In contrast, the mean price of equivalent conventional cars has increased by 21%, rising from 180 ± 30 EUR2015/kW in 2010 to 220 ± 50 EUR2015/kW in 2016 (Fig. 6).

While prices for individual models vary widely, the overall decline in electric car prices, though they still tend to be pricier on average compared to conventional counterparts, indicates significant technological advancements in powertrain electrification.

The experience curve analysis highlights learning rates of 23 ± 2% and 6 ± 1% for the specific prices of electric cars and plug-in hybrids, respectively (Fig. 8). Furthermore, higher learning rates of 32 ± 2% and 37 ± 2% are observed for the price differentials between electric cars and plug-in hybrids and their conventional counterparts (Fig. 8b)

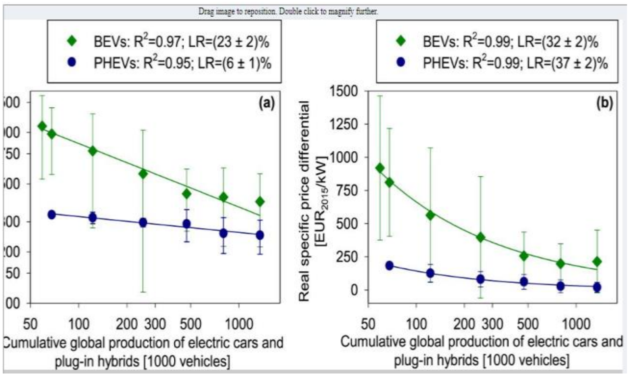


Fig. 8 Three experience curves depict the average specific price (a) and the average specific price

differential (b) for electric cars and plug-in hybrids. The error intervals indicate the standard deviation of the data

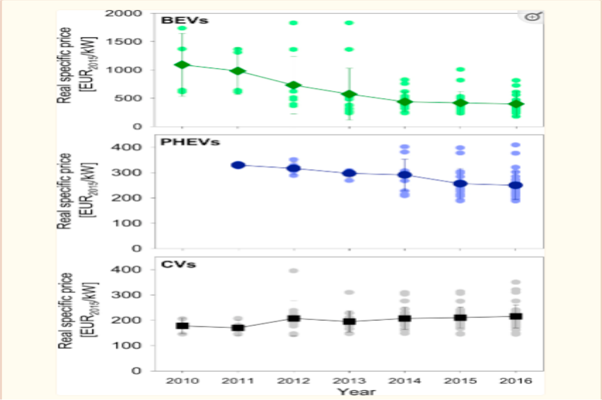


Fig. 9 illustrates the specific prices of electric cars (BEVs), plug-in hybrids (PHEVs), and conventional cars (CVs) sold in Germany. The squares represent the mean prices, while the error intervals denote the standard deviation of the price data

The average price difference between electric and conventional cars has decreased from 920 ± 540 EUR2015/kW in 2010 to 214 ± 237 EUR2015/kW in 2016. Similarly, the mean price difference between plug-in hybrid and conventional cars has reduced from 182 ± 11 EUR2015/kW in 2011 to 20 ± 38 EUR2015/kW in 2016, indicating that plug-in hybrids are approaching price parity with comparable conventional cars. When expressing the price of electric cars in relation to battery capacity, a learning rate of 16 ± 2% is observed.

Under the assumptions that (i) the learning rates for electric cars and plug-in hybrids continue in the future and (ii) the prices of conventional cars remain at 2016 levels, an additional 7 ± 1 million electric cars and 5 ± 1 plug-in hybrids need to be manufactured to achieve price parity with conventional cars. These figures are notably low and account for less than 10% of the annual global production of passenger cars

E. Time-Series of User Costs

User costs do not align with the trend of vehicle prices but tend to remain steady for electric cars or increase for plug-in hybrids and conventional cars from 2010 to 2016 (Fig. 3a). This observation suggests that the reduction in specific vehicle prices is offset by a tendency toward more powerful vehicles, leading to an increase in overall vehicle prices as well as electricity and fuel consumption of vehicles (Zerfass, 2017). In 2016, users incurred costs of 0.74 ± 0.46 EUR2015/km for electric cars, 1.06 ± 0.41 EUR2015/km for plug-in hybrids, and 0.71 ± 0.44 EUR2015/km for their conventional counterparts. The latter figure represents the user costs for all conventional cars included in our analysis.

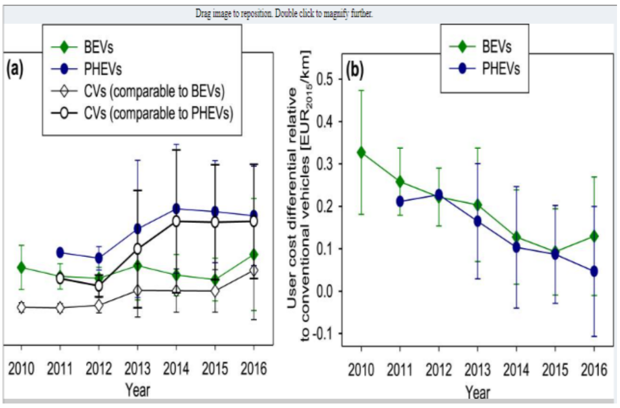


Figure 10 illustrates the average user costs (a) for electric cars (BEVs), plug-in hybrids (PHEVs), and conventional cars (CVs), along with the mean differential user costs of electric cars and plug-in hybrids compared to conventional cars (b). The error intervals signify the standard deviation of the data...

The user costs for electric cars, plug-in hybrids, and their conventional counterparts decrease to 0.51 ± 0.30 EUR2015/km, 0.75 ± 0.27 EUR2015/km, and 0.52 ± 0.29 EUR2015/km in 2016, considering an extended vehicle lifetime of 11 years and 150,000 km (Table S7 in the Supplementary Material). The elevated user costs of plug-in hybrids compared to electric cars can be attributed to their higher absolute price, power, and electricity/fuel consumption.

The differential user costs of electric cars and plug-in hybrids relative to conventional cars have witnessed a 60% and 78% decline during the analysis period, translating to an annual reduction of 14% and 26%, respectively. By 2016, electric cars and plug-in hybrids incurred 0.13 ± 0.14 EUR2015/km and 0.05 ± 0.15 EUR2015/km more in costs for their users than conventional cars (Fig. 3b), suggesting that, on average, the former cannot recover their price premium within a 6-year lifetime.

Costs Of Mitigating Carbon Dioxide Emissions

The carbon dioxide (CO2) emissions from electric, plug-in hybrid, and conventional cars vary based on different scenarios. Consequently, the expenses linked to reducing CO2 emissions from conventional vehicles by adopting electric and plug-in hybrid cars depend on the specific scenario. Figure 11 presents the following findings:

- The costs for mitigating CO2 emissions in individual electric and plug-in hybrid cars exhibit a broad range in all four scenarios. The limited data from vehicle samples between 2010 and 2014 make it challenging to identify a consistent cost trend. Mitigation costs can be notably high when the CO2 emission savings of electric and plug-in hybrid cars, compared to conventional counterparts, are minimal.

- The median CO2 mitigation costs of electric cars generally decline from 2010 to 2016 in all scenarios

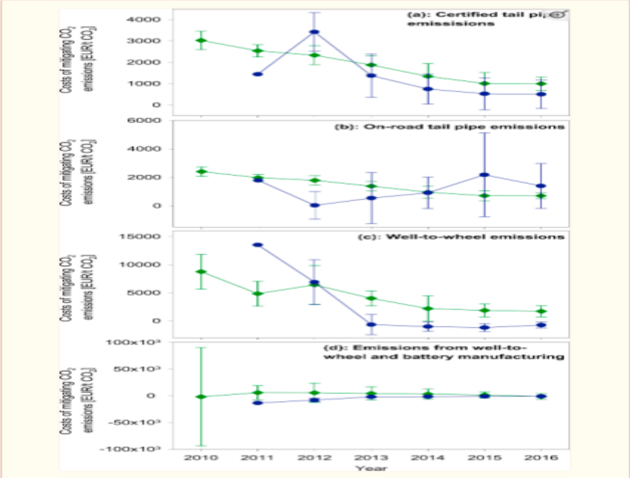


Fig. 11 Median expenses for mitigating CO2 emissions from conventional cars using electric cars (depicted by green diamonds) and plug-in hybrids (represented by blue circles) are presented across various scenarios:(a) Certified Tailpipe Emissions.

Costs of mitigating nitrogen oxides and particle number emissions

Electric and plug-in hybrid vehicles possess the ability to reduce NOx and particle number emissions. The mitigation costs associated with electric cars generally show a declining trend from 2010 to 2016 across all three scenarios, as illustrated in Figure 12. In contrast, the mitigation costs for plug-in hybrids do not exhibit a consistent trend. Notably, the costs incurred by electric cars are significantly low when conventional cars of comparable types demonstrate high emission levels, as seen in the case of NOx emissions from diesel cars (refer to Fig. 12a). Specifically, the median costs for electric cars decrease by 67% (to 1.8 × 106 EUR/t NOx) and 48% (to 3.0 × 105 EUR/t NOx) between 2010 and 2016 for mitigating the tailpipe NOx emissions of gasoline and diesel vehicles, respectively

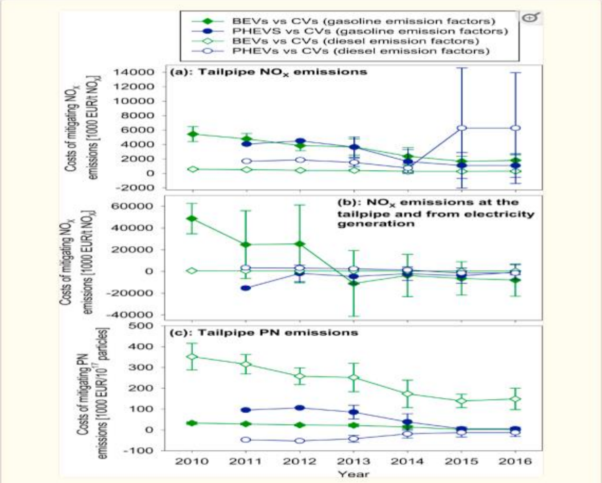


Fig 12 The median expenses for mitigating NOx and particle number (PN) emissions from conventional gasoline and diesel cars, utilizing electric cars (BEVs) and plug-in hybrids (PHEVs), are illustrated in Figures (a, c). Additionally, Figure (b) represents a combination of tailpipe emissions and indirect NOx emissions from electricity generation. Error intervals are incorporated, reflecting half of the interquartile range of cost data. It is important to note that the limited sample size of one model hinders the presentation of an error interval for plug-in hybrid cars in 2011

Considering the indirect NOx emissions from electricity generation, both electric cars (in 2014 and 2016) and plug-in hybrids, on average, release more NOx than their conventional counterparts, as evidenced by the disparities between Fig. 12 a and b The expenses linked to mitigating particle number emissions by electric cars have, on average, declined by 92% (from 3.3 × 104 EUR/10^17 particles to 2.7 × 103 EUR/10^17 particles) for gasoline cars and 58% (from 3.5 × 105 EUR/10^17 particles to 1.5 × 105 EUR/10^17 particles) for diesel cars between 2010 and 2016.

V. CONCLUSION

This paper has focused on Embracing a hybrid approach for electric vehicle (EV) charging stations, integrating both renewable and conventional energy sources alongside energy storage solutions, presents a comprehensive and effective strategy. This method adeptly addresses issues related to the intermittent nature of renewable energy, thereby promoting sustainability and reducing the overall environmental footprint of electric transportation. As technological progress continues, ongoing improvements in hybrid systems are expected to play a crucial role in shaping a more efficient and sustainable future for EV charging.

Diverse Energy Sources: A hybrid approach typically involves combining renewable energy sources such as solar and wind with conventional sources or energy storage systems. This integration effectively addresses the intermittent nature of renewable sources, ensuring a more consistent and reliable power supply for electric vehicle (EV) charging.

Reliability and Consistency: Incorporating conventional power sources, such as the electrical grid or backup generators, provides reliability and consistency in charging, especially during periods of low renewable energy generation. This ensures that EV users have a dependable charging infrastructure regardless of weather conditions or time of day.

Energy Storage Integration: Hybrid systems frequently incorporate energy storage solutions such as batteries. These batteries are designed to store surplus energy produced during peak renewable generation times and release it during periods of low production. This contributes to a more stable and continuous power supply for electric vehicle (EV) charging.

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