*Int. J. Econ. Environ. Geol. Vol. 15 (3) 32-40, 2024*
*Journal home page: www.econ-environ-geol.org*

***Open Access***
***ISSN: 2223-957X***

# Energy Storage Innovations in the Context of Electric Vehicles and Smart Grid Integration: A Review

**Ehtesham Ali[1], Rahool Rai[2*], Muhammad Aleem[3], Rafiq Asghar[4], Rittick Maity[1]**

[1]Faculty of Electrical and Electronics Engineering Technology, University Malaysia Pahang Al-Sultan Abdullah, Pekan, Pahang, Malaysia.
[2]Faculty of Mechanical and Automotive Engineering Technology, University Malaysia Pahang Al-Sultan Abdullah, Pekan, Pahang, Malaysia
[3]Faculty of Computing, University Malaysia Pahang Al-Sultan Abdullah, Pekan, Pahang, Malaysia
[4]Department of Industrial, Electronic and Mechanical Engineering, Roma Tre University, Via V. Volterra Rome, Italy

***E-mail:** rahool.rai@hamdard.edu

***Received**: 10 April, 2024* ***Accepted**: 11, November 2024*

**Abstract**: The integration of electric vehicles (EVs) with the smart grid presents a transformative solution for achieving energy efficiency and environmental sustainability. This paper explores advanced energy storage devices and management systems that enhance the operational flexibility and stability of EVs within a smart grid context. By enabling bidirectional power flows in Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) modes, EVs not only function as transportation but also as distributed energy resources that support grid demand management, especially during peak and off-peak hours. This paper shows that lithium-ion (Li-ion) and sodium-nickel chloride (Na-NiCl) batteries exhibit superior energy density and efficiency, making them ideal for EV applications where high energy storage and extended cycle life are crucial. The study reveals that Li-ion polymer batteries, with their high specific energy, are widely used in portable devices and EVs, while Na-NiCl batteries, with the highest efficiency (92.5%), are particularly suited for long-term energy storage. The study provides new insights into managing EV energy storage within a smart grid by enabling stable, bidirectional energy flows. Additionally, smart grid integration through wide-area EV networks can stabilize grid operations by balancing supply-demand dynamics, reducing $CO_2$ emissions, and enhancing energy resilience. The implications for EV infrastructure, policy, and future technological development highlight EVs' role in advancing sustainable, high-efficiency energy systems.

**Keywords:** Electric vehicles, energy efficiency, energy storage devices, green environment, smart grid.

## Introduction

EV is a promising technology that utilizes an internal combustion engine, compared to conventional vehicles that emit Carbon Oxides ($CO_2$), Nitrogen Oxides (NOx), and unburned Hydrocarbons (HC), the main causes of air pollution (Guille Des Buttes et al., 2020). The world's energy development is experiencing unprecedented change in a century. The widespread development and use of fossil energy has accelerated human civilization's progress, but it has also resulted in resource depletion, environmental pollution, climate change, and other serious issues. $CO_2$ emission is a major factor of global warming. Increase in $CO_2$ emission results in increased global temperature. $CO_2$ emissions reached the 37.55 Giga Ton mark By the year 2023 (Adebayo et al., 2022; IEA, 2023, 2024; Sunday et al., 2023). Forty-Nine 49% of GHG emission is contributed by electric power generation sector. Transportation is the major contributing factor in pollution. Thus, by replacing conventional vehicles with EVs, pollution will decrease drastically. EVs play a pivotal role in reducing air pollution. EVs contribute towards the green environment by reducing $CO_2$ emissions, producing low tariff rates, low maintenance costs, reduced noise pollution, power injection, and absorption in prosumers mode. The recent research in SG highlights electrification of transportation. SG is a modernized power distribution system that enhances the capability of monitoring, protecting and automatically optimizing SG operations. This includes generation, transmission, distribution, EVs, and consumer appliances (Muqeet et al., 2023). SG network provides opportunities for implementation of advanced communication system that improves reliability of electric power services (Rodriguez et al., 2023), such as: (a) consumer empowerment, (b) power injection and absorption, (c) consumer and utility through bidirectional communication infrastructure, and (d) pollution free environment. SG infrastructure is illustrated in Figure 1. SG has a capability to interconnect various systems, such as (a) local grid with power generation plants through high voltage transmission lines, (b) renewable and non-renewable energy sources, (c) Smart Homes (SHs), and (d) EV charging stations by using intelligent system of Advanced Metering System (AMI). SG guarantees: (a) energy efficient SHs, (b) optimized energy-flow, and (c) reduced energy costs. SG is heading towards Mega Grid (MG) technology. EV enhances SG transportation economics and controlled energy flows. EVs operate in two modes, namely: (a) Vehicle to Grid (V2G) and (b) Grid to the vehicle (G2V). In V2G and G2V modes, energy flow and communication flow occur bi-directionally with SG through grid operator’s control signal. EV management system includes Smart Meter (SM) to evaluate real-time communication, control, and energy flows. Power is generated, transmitted to a wide transmission system, and finally delivered to consumers through a distribution control system in the conventional power system. SG system consumers enable to produce electricity using domestic solar panels, waste heat recovery, wind turbines and transfer surplus power to them.

Various generic state-of-the art reviews and articles on V2G and G2V exist in the literature review. For example, Zhang et al. (2014) described the use of PEVs as Distributed Energy Storages (DES) in SG and gave brief overview on: (a) PEV infrastructure, and (b) V2G operations. (Mwasilu et al., 2014) reviewed and explained: (a) EVs, (b) PHEVs, (c) Batteries used for energy storage, and (d) V2G communications. (Chandwani et al., 2020) and (Komninos et al., 2014) explored EVs security issues, challenges, and countermeasures in SG (Guizani & Anan, n.d.). Discussed the SG architecture and challenges of integrating EVs and renewable sources. Al-Badi et al. (2020) elaborated the concepts of EVs in SG architectures. Bibak et al. (2021) prepared a report on a study of governmental regulations and building code requirements for introduction and use of vehicles with V2G capability.

In this paper, authors presented study about: (a) Operational modes of PEVs and storage (b) V2G operating modes, and (c) International codes and standards used for SG. Andreotti et al. (2012) presented an overview of Single-Objective Optimization methodologies for PEVs operation in SG. Dai et al. (2016) presented a survey on EVs and renewable energies synergies in SG. Mellouk et al. (2015) described mathematical models for Energy Management Optimization in SG. Shuai et al. (2016) explained an economy driven approach for charging EVs in Smart city. Teixeira et al. (2015) explored EVs interaction within SG for Brazil. Innovations in fast-charging infrastructure and battery-swapping systems further enhance convenience for EV users, while reducing grid strain. EVs are increasingly recognized as Distributed Energy Storages (DES), facilitating Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) operations. Challenges like range anxiety, charging infrastructure gaps, and peak demand management are addressed through innovative solutions such as superfast charging stations, battery-swapping systems, and electrified roads.

## Global Perspectives and Policies

The existing research objective primarily covers the lithium ion (Li-ion) batteries, but there is a research gap regarding Sodium Nickel Chloride (Na-NiCl) batteries and their application for long term storage in electric vehicles. This paper focusses on the energy efficiency, energy density and cycle life for different energy storage. Although the smart grid's capabilities have been studied extensively, gaps remain in practical, real-time energy management systems that effectively incorporate EVs. This paper examines advanced energy management systems that coordinate bidirectional flows and stabilize grid performance through real-time interaction.

The study provides new insights into managing EV energy storage within a Smart Grid by enabling stable and bidirectional energy flows. This novel approach facilitates the use of EVs as storage assets, contributing to overall grid efficiency and energy resilience during periods of fluctuating demand. The research uniquely emphasizes Na-NiCl batteries, which are often overlooked, but offer high efficiency (92.5%) and are suited for long-term applications. By comparing these with Li-ion batteries, the paper provides a fresh perspective on battery technology selection tailored to various EV and grid scenarios. A significant novel aspect is the concept of Wide Area Electric Vehicle Systems (WAEVs), which could enhance grid operations by supporting real-time stability and control. This approach introduces an innovative method to integrate a growing fleet of EVs into the smart grid, ensuring that they positively impact grid reliability rather than overwhelm it. Existing studies provide fragmented insights into battery advancements (e.g., Solid-state, LFP, and graphene batteries), and their potential in V2G and SG applications. This study integrates these advancements, evaluating their implications for system efficiency, safety, and long-term sustainability.

**Table 1.** Properties of various rechargeable batteries (Ireland, 2007).

| Battery type | LDH | P/W (W/kg) | NoC | EE | ED | SD Per 24h | SE (Wh/kg) | EV (Wh/litr e) |
|---|---|---|---|---|---|---|---|---|
| **NaNiCl** | 7.20% | NA | 1,000 | 92.5 | 313% | 0% | 125 | 300 |
| **Li-ion polymer** | NA | >3,000 | NA | NA | 500% | NA | 200 | 300 |
| **NiMH** | NA | 250-1000 | 1,350 | 70% | 175% | 2% | 70 | 140-300 |
| **Li-ion** | NA | 1800 | 1,000 | 90% | 313% | 1% | 125 | 270 |
| **NiCd** | NA | 150 | 1,350 | 72.5% | 150% | 5% | 60 | 50-150 |
| **Pb-acid** | NA | 180 | 500 | 82.5% | 100% | 1% | 40 | 60-75 |

**Abbreviations**
SE = Specific Energy; P/W = Power/Weight; EE = Energy Efficiency
EV = Energy Volume; NoC = Number of Cycles; ED = Energy Density
SD =Self Discharge; LDH =Losses due to Heating

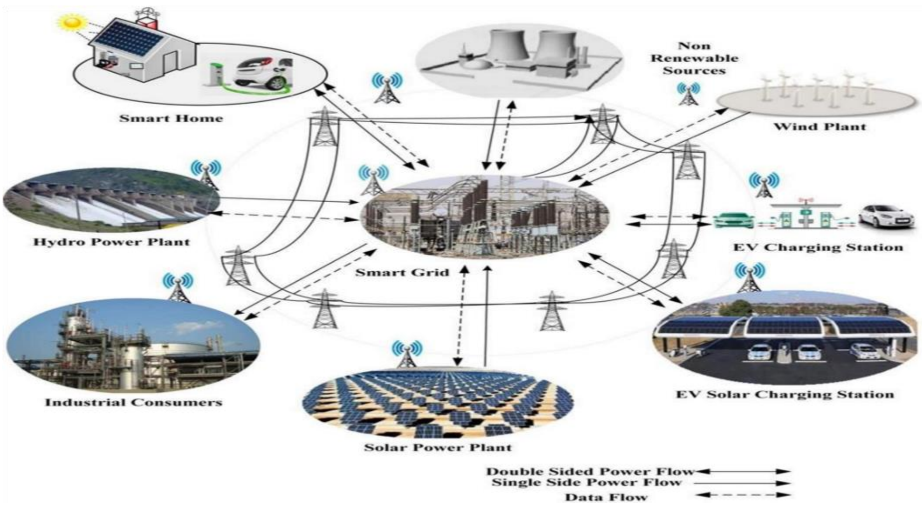


**Fig .1** SG infrastructure

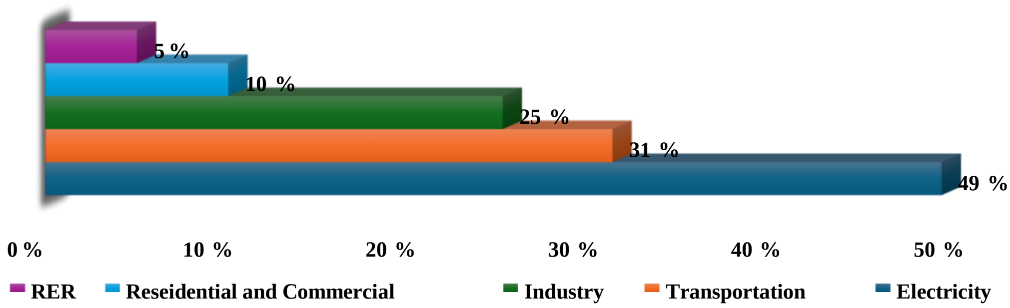


**Fig. 2** Sector wise emission of GHG (Chukwu & Mahajan, 2014).

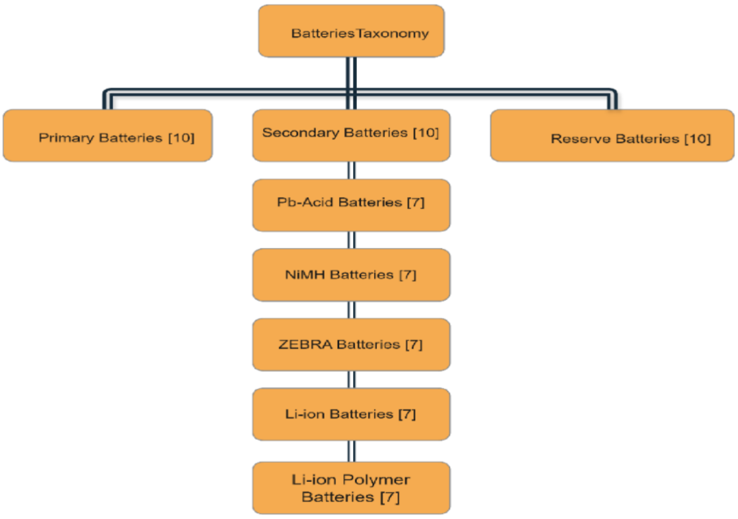


**Fig. 3** Taxonomy of batteries.

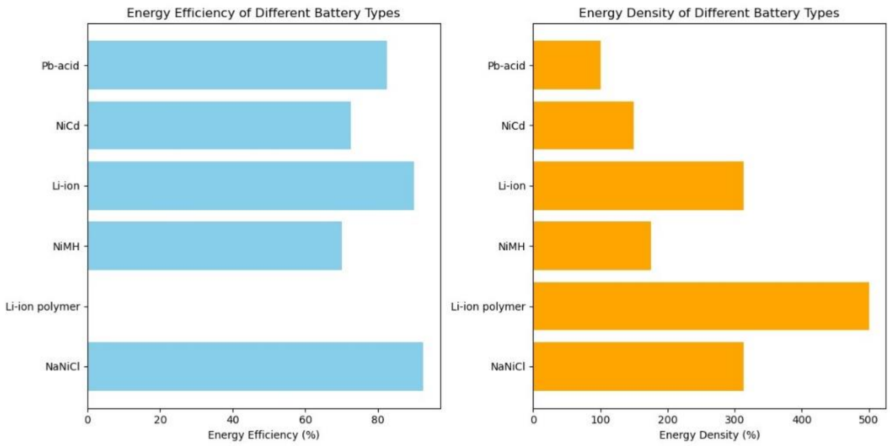


**Fig. 4** Comparison of energy density and energy efficiency across different battery types (Matheys et al., 2009).

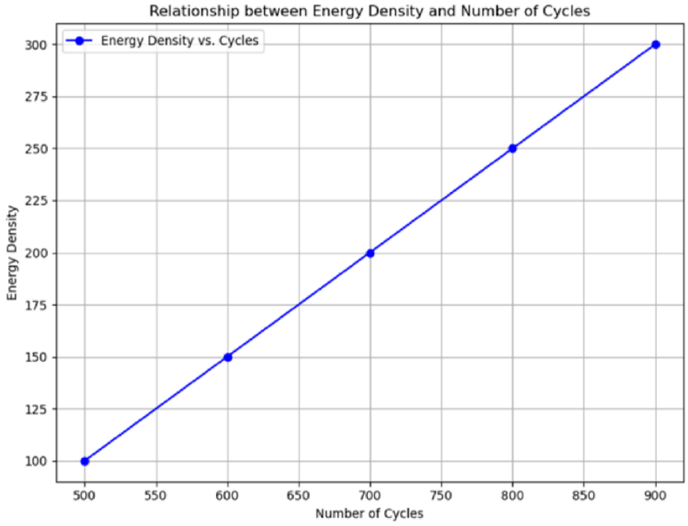


**Fig. 5** Correlation between energy density and cycle lifespan of a typical battery storage (Matheys et al., 2009).

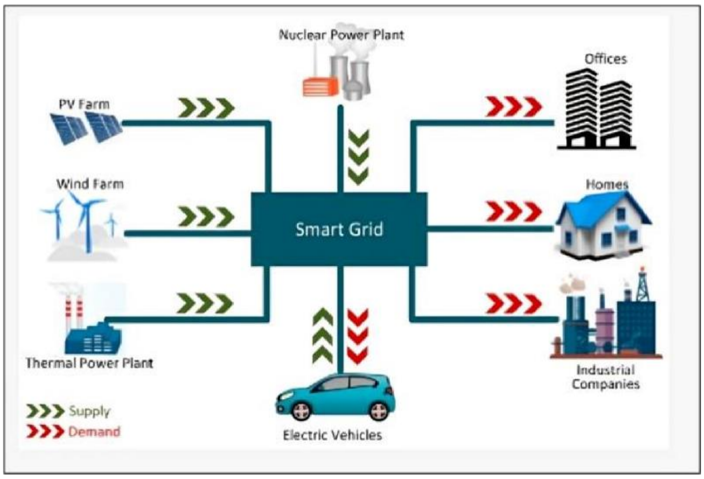


**Fig. 6** Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) Processes in Smart Grids (İnci et al., 2024).

## Battery Fundamentals, Classifications and Advances in Cell Technologies

A battery changes chemical energy into electrical energy with help of an electrochemical oxidation reduction (redox) reaction (Soni et al., 2015). A rechargeable battery uses a reversible process to generate electrical energy through chemical reactions. Its cells are connected in series, parallel, or both to produce the desired voltage. The anode oxidizes electrons before supplying them to the load, whereas the cathode reduces them. An electrolyte, usually a liquid containing dissolved salts, alkalis, or acids, aids in ion transfer between electrodes. Some batteries use solid electrolytes at operating temperatures. Ideal anodes are lightweight, high-voltage, and cost effective, with a high conductivity. Cathodes should be stable, with a high oxidation efficiency and operating voltage. To prevent short circuits, the electrolyte must be ionically conductive, but not electrically conductive.

## Classification of Batteries

Batteries are classified into three main classes based on battery charging and discharging characteristics, described in Figure 4. Primary batteries are the batteries that are discarded after discharging (Lee et al., 2022). Secondary batteries are rechargeable. They are recharged after discharged. Secondary batteries have many applications, such as secondary batteries are used in EVs and many portable devices (Guarnieri, 2022). The third type of batteries are reserve batteries which are used as standby batteries.

### Primary batteries

These batteries are not electrically rechargeable. They are discarded after if discharged once. Many primary cells are also referred as dry cells, if they have absorbents in them. Primary batteries are easy to use, having low cost, and light in weight, and are used in many portable electric and electronic devices, such as watches and toys (Takeuchi et al., 2022). The primary batteries have many benefits, such as long service life, low discharge rate, high energy density, and little maintenance (Liu et al., 2022a).

### Secondary batteries

The batteries that can be recharged electrically are termed as secondary batteries. They are also known as energy storage batteries' and accumulators as well. Secondary batteries have high discharge rate, high power density, and good performance at low temperature, but have low energy density than primary batteries (Liu et al., 2022b). Secondary batteries have the following two main applications. These batteries are used for storing energy electrically connected to and deliver the required power and charged by a primary source (Hassan et al., 2023). Examples of secondary batteries are aircraft and automotive system batteries, no fail and standby power batteries, Stationary Energy Storage (SES) systems and Hybrid Electric Vehicles (HEVs).The applications, where secondary batteries are essentially discharged, as a primary battery can be recharged after discharging. Such batteries are used in portable consumer electronics, EVs and power tools etc.

**Reserve batteries**

Reserve batteries are also called standby batteries. In such type of batteries, self-discharge is necessarily eliminated because the main component of the battery is isolated before the activation and battery has the capacity of storage for a long time (Khan et al., 2023). In some systems like thermal batteries, the batteries are inactive as long as they are not heated and a solid electrolyte only conducts when it is melted. Adding water, electrolyte or gas into the cell may activate reserve batteries (Park et al., 2021). We use reserve batteries, during storage for long time. Reserve batteries are used in EVs, missiles, bomb fuzzes, and various weapon systems.

## Cell Technologies

Battery technology is under research, to increase energy lend and reduce batteries cost. The main drawbacks of EVs are slow charging, low life cycle, and high costs. Researchers are trying to improve cell technologies to eliminate the problems. The United States Advanced Battery Consortium (USABC) has targeted distinct goals to get fully Electrical Vehicle (EV) battery pack by 2020 (Castro et al., 2021). Table 1 describes disposable alkaline batteries typically self-dischargeable than rechargeable batteries. Table 1 also elaborates the specific energy and energy density of Li-ion polymer batteries as compared with other rechargeable batteries. Table 1 clearly shows that Li-ion polymer and Na-NiCl batteries have the same energy volume. Moreover, the energy efficiency of Na-NiCl batteries is up to 92.5% and that of Li-ion batteries is 90% which counts to number second after Na-NiCl batteries. Furthermore, available Lithium based batteries are more advanced in this respect. EVs can travel more distance, if they have high energy density. Therefore, energy to weight ratio may spread up the market of EVs.

## Results and Discussion

The research provides a thorough examination of the applications of primary, secondary, and reserve batteries in a variety of technological disciplines, with a particular emphasis on electric vehicles (EVs). Portable electronic devices primarily employ primary batteries, which are distinguished by their high energy density, low discharge rate, and extended service life. Conversely, secondary batteries, which are rechargeable, exhibit a high discharge rate and power density, rendering them appropriate for applications that require dependable energy storage, such as standby power systems, aircraft, and electric vehicles. Secondary batteries, particularly lithium-ion (Li-ion) and sodium nickel chloride (Na-NiCl) batteries, are at the vanguard of EV battery technology as a result of their high energy efficiency and energy density, as indicated by the data. Li-ion and Na-NiCl batteries are the preferred option for electric vehicles (EVs), as they outperform other types. This choice contributes to an increase in the range and performance of the vehicle.

A thorough comparison of several rechargeable batteries, such as Pb-acid, Li-ion polymer, NiMH, NiCd, and Na-NiCl batteries is given in Table 1. The findings support the widespread usage of Li-ion polymer batteries in EVs and portable gadgets since they have a higher specific energy (500 Wh/kg) than conventional batteries. In contrast, Na-NiCl batteries have the highest energy efficiency (92.5%), which makes them perfect for applications that need long-term energy storage. Additionally, the analysis shows that even while NiMH and NiCd batteries have a high cycle count (1,350 cycles), they are less appropriate for use in contemporary electric vehicle applications due to their lower energy efficiency and higher rates of self-discharge. The link between energy density and cycle life shows that Li-ion and Na-NiCl batteries provide the optimum compromise between these two crucial factors (Fig. 5).

It is highlighted that integrating EV batteries into Smart Grid is a crucial tactic for enhancing energy efficiency and grid stability. Known as Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G), the bidirectional flow of power enables EVs to function as energy providers and consumers, assisting in the regulation of supply and demand. This skill is essential for controlling intermittent renewable energy sources like wind and solar. The G2V and V2G processes are depicted in Figure 6, which also demonstrates how EVs can store excess energy during off-peak hours and return it to the grid during peak demand, improving grid stability and lowering the possibility of blackouts. As EV adoption rises, the talk also emphasizes how Wide Area Electric Vehicle Systems (WAEVs) may help further optimize Smart Grid performance. By offering real-time stability and control analysis, this technology might make sure that the increasing number of electric vehicles (EVs) linked to the grid improves overall efficiency rather than reduces it.

## Conclusion

Electric vehicles (EVs) have revolutionized transportation with hybrid and green technology, offering better mileage and reduced $CO_2$ emissions. Designed for efficiency, EVs use lightweight, aerodynamic structures and compact batteries, primarily Li-ion, due to their superior performance. EVs also play a key role in smart grids, storing excess renewable energy during off peak hours (G2V) and supplying power back during peak demand (V2G), enhancing grid stability and reducing blackouts. Their integration with smart grids helps optimize renewable energy use, making electricity distribution more reliable and sustainable. As EV adoption grows, integrating millions into the grid presents challenges such as increased electricity demand, infrastructure upgrades, and the need for widespread charging stations. Managing renewable energy intermittency, ensuring bidirectional power flow, and addressing battery wear are critical concerns. Additionally, cyber security risks, lack of standardized charging protocols, and high initial costs hinder seamless EV-grid integration. Addressing these issues requires grid modernization, advanced energy management, and supportive policies for sustainable EV adoption. Collaboration between governments, industries, and research institutions will be essential in overcoming these challenges and ensuring the smooth transition to an EV powered future.

## Acknowledgement

The authors are grateful to the University Malaysia Pahang Al-Sultan Abdullah (UMPSA) for their support and facilities. We express our sincere gratitude to the researchers whose work was instrumental in the literature review for this study. We also thank the anonymous reviewers for their Insightful comments, which have greatly improved the content of this manuscript.

## References

Adebayo, T. S., Pata, U. K., Akadiri, S. S. (2022). A comparison of $CO_2$ emissions, load capacity factor, and ecological footprint for Thailand's environmental sustainability. *Environment, Development and Sustainability*, ***26***(1), 2203–2223. https://doi.org/10.1007/s10668-022-02810-9

Al-Badi, A., Ahshan, R., Hosseinzadeh, N., Ghorbani, R., Hossain, E. (2020). Survey of smart grid concepts and technological demonstrations worldwide emphasizing on the Oman perspective. *Applied System Innovation*, ***3***(1), 5. https://doi.org/10.3390/asi3010005

Andreotti, A., Carpinelli, G., Mottola, F., Proto, D. (2012). A review of single-objective optimization models for plug-in vehicles operation in smart grids part II: numerical applications to vehicles fleets. *IEEE Power and Energy Society General Meeting*, 1–8. https://doi.org/10.1109/PESGM.2012.634590

Bibak, B., Tekiner-Moğulkoç, H. (2021). A comprehensive analysis of vehicle to grid (V2G) systems and scholarly literature on the application of such systems. *Renewable Energy Focus*, ***36***, 1–20. https://doi.org/10.1016/j.ref.2020.10.00

Castro, M. T., Del Rosario, J. A. D., Chong, M. N., Chuang, P.-Y. A., Lee, J., Ocon, J. D. (2021). Multiphysics modeling of lithium-ion, lead-acid, and vanadium redox flow batteries. *Journal of Energy Storage*, ***42***, 102982. https://doi.org/10.1016/j.est.2021.102982

Chandwani, A., Dey, S., Mallik, A. (2020). Cybersecurity of onboard charging systems for electric vehicles—review, challenges and countermeasures. *IEEE Access*, ***8***, 226982–226998. https://doi.org/10.1109/ACCESS.2020.3045367

Chukwu, U. C., Mahajan, S. M. (2014). Real-time management of power systems with V2G facility for smart-grid applications. *IEEE Transactions on Sustainable Energy*, ***5***(2), 558–566. https://doi.org/10.1109/TSTE.2013.2273314

Dai, J., Dong, M., Ye, R., Ma, A., Yang, W. (2016). A review on electric vehicles and renewable energy synergies in smart grid. *2016 China International Conference on Electricity Distribution (CICED)*, 1–4. https://doi.org/10.1109/CICED.2016.7575995

Secondary Batteries for Mobile Applications: From Lead to Lithium [historical]. *IEEE Industrial Electronics Magazine*, ***16***(4), 60–68. IEEE Industrial Electronics Magazine**.** https://doi.org/10.1109/MIE.2022.3212242

Guille Des Buttes, A., Jeanneret, B., Kéromnès, A., Le Moyne, L., Pélissier, S. (2020). Energy management strategy to reduce pollutant emissions during the catalyst light-off of parallel hybrid vehicles. *Applied Energy*, ***266***, 114866. https://doi.org/10.1016/j.apenergy.2020.114866

Guizani, M., Anan, M. (n.d.). SG opportunities and challenges of integrating renewable sources: A survey. 1098–1105.

Hassan, A., Khan, S., Li, R., Su, W., Zhou, X., Wang, M., Wang, B. (2023). Second-life batteries: A review on power grid applications, degradation mechanisms, and power electronics interface architectures. *Batteries*, ***9***(12), 571. https://doi.org/10.3390/batteries9120571

IEA (2024),. (2023). *$CO_2$ Emissions in 2023* (No. Paris https://www.iea.org/reports/co2-emissions-in-2023, Licence: CC BY 4.0) [Dataset].

İnci, M., Çelik, Ö., Lashab, A., Bayındır, K. Ç., Vasquez, J. C., Guerrero, J. M. (2024). Power system integration of electric vehicles: a review on impacts and contributions to the smart grid. *Applied Sciences*, ***14***(6), 2246. https://doi.org/10.3390/app14062246

Ireland, S. E. (2007). Hybrid electric and battery electric vehicles. *AEA Energy & Environment*.

Khan, T., Garg, A. K., Gupta, A., Madan, A. K., Jain, P. K. (2023). Comprehensive review on latest advances on rechargeable batteries. *Journal of Energy Storage*, ***57***, 106204. https://doi.org/10.1016/j.est.2022.106204

Komninos, N., Philippou, E., Pitsillides, A. (2014). Survey in smart grid and smart home security: issues, challenges and countermeasures. *IEEE Communications Surveys & Tutorials*, ***16***(4), 1933–1954. https://doi.org/10.1109/COMST.2014.2320093

Lee, C.-H., Cheng, H.-W., Liao, B.-W., Jiang, J.-A. (2022). An approach to recover energy from discarded primary batteries before being disassembled. *IEEE Transactions on Industrial Electronics*, ***69***(6), 6247–6257. IEEE Transactions on Industrial Electronics. https://doi.org/10.1109/TIE.2021.3088367

Liu, W., Placke, T., Chau, K. T. (2022a). Overview of batteries and battery management for electric vehicles. *Energy Reports*, ***8***, 4058–4084. https://doi.org/10.1016/j.egyr.2022.03.016

Liu, W., Placke, T., Chau, K. T. (2022b). Overview of batteries and battery management for electric vehicles. *Energy Reports*, ***8***, 4058–4084. https://doi.org/10.1016/j.egyr.2022.03.016

Matheys, J., Timmermans, J.-M., Van Mierlo, J., Meyer, S., Peter Van den Bossche. (2009). Comparison of the environmental impact of five electric vehicle battery technologies using LCA. *International Journal of Sustainable Manufacturing*, ***1***(3), 318–329. https://doi.org/10.1504/IJSM.2009.023977

Mellouk, L., Aaroud, A., Benhaddou, D., Zine-Dine, K., Boulmalf, M. (2015). Overview of mathematical methods for energy management optimization in smart grids. *2015 3rd International Renewable and Sustainable Energy Conference (IRSEC)*, 1–5. https://doi.org/10.1109/IRSEC.2015.7454972

Muqeet, H. A., Liaqat, R., Jamil, M., Khan, A. A. (2023). A state-of-the-art review of smart energy systems and their management in a smart grid environment. *Energies*, ***16***(1), 472. https://doi.org/10.3390/en16010472

Mwasilu, F., Justo, J. J., Kim, E.-K., Do, T. D. Jung, J.-W. (2014). Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration. *Renewable and Sustainable Energy Reviews*, ***34***, 501–516. https://doi.org/10.1016/j.rser.2014.03.03

Park, T.-R., Park, H., Kim, K., Im, C.-N., Cho, J.-H. (2021). Heat and weight optimization methodology of thermal batteries by using deep learning method with multi-physics simulation. *Energy Conversion and Management*, ***236***, 114033. https://doi.org/10.1016/j.enconman.2021.114033

Rodriguez, J. C., Grijalva, F., García, M., Chérrez Barragán, D. E., Acuña Acurio, B. A., Carvajal, H. (2023). Wireless communication technologies for smart grid distribution networks. *XXXI Conference on Electrical and Electronic Engineering*, **7**. https://doi.org/10.3390/engproc2023047007

Shuai, W., Maille, P., Pelov, A. (2016). charging electric vehicles in the smart city: A survey of economy-driven approaches. *IEEE Transactions on Intelligent Transportation Systems*, ***17***(8), 2089–2106. https://doi.org/10.1109/TITS.2016.2519499

Soni, S. R., Upadhyay, C. D., Chandwani, H. (2015). Analysis of battery-super capacitor based storage for electrical vehicle. *2015 International Conference on Energy Economics and Environment (ICEEE)*, 1–7. https://doi.org/10.1109/EnergyEconomics.2015.7235110

Sunday Adebayo, T., Saint Akadiri, S., Haouas, I., Rjoub, H. (2023). A time-varying analysis between financial development and carbon emissions: Evidence from the MINT countries. *Energy & Environment*, ***34***(5), 1207–1227. https://doi.org/10.1177/0958305X221082092

Takeuchi, E. S., Takeuchi, K. J., Marschilok, A. C. (2022). The ongoing importance of lithium primary batteries: 50+ years and going strong. *ECS Meeting Abstracts*, *MA2022-02*(2), 102. https://doi.org/10.1149/MA2022-022102mtgabs

Teixeira, A. C. R., Da Silva, D. L., Machado Neto, L. D. V. B., Diniz, A. S. A. C., Sodré, J. R. (2015). A review on electric vehicles and their interaction with smart grids: The case of Brazil. *Clean Technologies and Environmental Policy*, ***17***(4), 841–857. https://doi.org/10.1007/s10098-014-0865-x

Wang, Q., Liu, X., Du, J., Kong, F. (2016). Smart charging for electric vehicles: A survey from the algorithmic perspective. *IEEE Communications Surveys & Tutorials*, ***18***(2), 1500–1517. https://doi.org/10.1109/COMST.2016.2518628

Zhang, X., Wang, Q., Xu, G.,Wu, Z. (2014). A review of plug-in electric vehicles as distributed energy storages in smart grid. *IEEE PES Innovative Smart Grid Technologies, Europe*, 1–6. https://doi.org/10.1109/ISGTEurope.2014.7