AUTOMATION AND OPTIMIZATION OF RENEWABLE DOMESTIC ENERGY PRODUCTION AND STORAGE USING ELECTRIC VEHICLES

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Due to global energy challenges marked by soaring costs and supply uncertainties, this thesis explores alternative approaches to domestic energy conservation, emphasizing the transformative potential of Electric Vehicles (EVs) and Vehicle-to-Home (V2H) technology. Addressing critical issues in household energy supply, the thesis aims to provide insights into the possibility of automating and optimizing renewable energy generation and storage using EVs.

With a focus on developing sustainable energy systems, the study assesses this innovative approach's practicality and economic implications, examining its potential for cost reduction and continuous energy supply. Through a survey involving 70 participants with an 80% response rate, the study analyses the current energy landscape, EV awareness, and integration challenges and benefits.

Despite acknowledged obstacles, respondents are interested in EVs' innovative energy storage potential. Recommendations highlight the importance of supportive policies, awareness campaigns, and sustainable practices to facilitate the widespread adoption of automated and optimized EV integration in domestic renewable energy systems.

The study concludes that the proposed approach is feasible and offers positive economic and environmental outcomes, calling for future research to address adoption barriers and enhance efficiency.

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List of abbreviations

Abbreviation	Definition
AC	Alternating Current
DERs	Distributed Energy Resources
DoD	Depth of Discharge
EVs	Electric Vehicles
ESA	European Space Agency
FBEV	Fully Battery Electric Vehicles
HEV	Hybrid Electric Vehicles
ICE	Internal Combustion Engine
IIoT	Industrial Internet of Things
KPIs	Key Performance Indicators
LSTM	Long Short-Term Memory
ML	Machine Learning
MV	Machine Vision
PLCs	Programmable Logic Controllers
PV	Photo Voltaic
PVGIS	Photovoltaic Geographical Information
SARIMA	Seasonal Autoregressive Integrated Moving Average
VBN	Value-Belief-Norm
V2H	Vehicle-to-Home

1 Introduction

The integration of renewable energy sources and Electric vehicles (EVs) has the potential to revolutionize domestic energy systems. This thesis explores the automation and optimization of renewable domestic energy products and storage by using EV. The aim is to improve energy efficiency by using surplus renewable energy to power EVs, resulting in positive economic and environmental impacts. The increasing demand for sustainable energy makes this an important area of research and development.

1.1 Background of the study

The energy crisis experienced across different parts of the world has necessitated exploring alternative approaches to energy conservation and efficient use at the domestic level. Many families across the globe grapple with the increase in cost of power and the unreliability of supplies. According to Guan et al. (2023), since the COVID-19 pandemic, households have experienced rising energy costs for heating, mobility, and other uses. The Russian-Ukraine conflict further affected the energy supply, leading to increased costs. Additionally, the climate change also necessitates a reconsideration of energy generation and conservation.

The innovation of EVs has improved clean energy adoption and usage efficiency. Vehicle-to-home (V2H) is another emergent technology that can aid households in addressing the problem of inconsistent and high energy costs for domestic use (Zafar et al., 2022). Integrating the EV into the home grid system is critical in ensuring families can efficiently store energy for different services. While the V2H technology has the potential to address home energy needs, its adoption remains low. The study explores the implications of automation and optimization of generating and storing renewable energy using EVs in domestic settings.

1.2 Problem statement

Household energy supply is critical for the health and well-being of the population, especially in parts of the world that experience adverse weather patterns. The increasingly unaffordable and inconsistent domestic energy supply remains a critical challenge that affects many families across the globe. In the current energy crisis, attaining energy security remains essential for populations worldwide. Berahab (2022) indicates that families should have sufficient access to energy resources at reasonable prices to be considered energy secure in the foreseeable future.

In the face of this challenge, EVs offer a potential solution to attaining energy security through generating and storing renewable energy. However, limited information is available on the solution's potential to improve energy security at the domestic level. Through the study, it will be possible to assess the potential of the automation and optimization of renewable energy generation and storage at household levels. This will be critical in determining its usefulness in addressing the energy crisis.

1.3 Rationale

The proposed study will focus on automating and optimizing renewable domestic energy generation and storage using EVs. The research underpins the need to develop sustainable energy systems that address homes' energy challenges. Mainly, the study is focused on addressing the cost of power and facilitating continuous energy supply through integrating the EV battery into the home renewable energy generation and storage grid.

Completion of the study will help provide a better perspective into ways the incorporation of electric vehicle batteries into the domestic energy systems can be automated and optimized for energy efficiency and reliability. Most importantly, it will be possible to assess the effectiveness of the automation and optimization to determine whether it is a practical approach to the V2H technology implementation as part of the efforts to address the energy problem in domestic settings.

1.4 Objectives of the study

This research aims to establish that exploring alternatives to address high energy costs is crucial in light of the ongoing transformations in the power system and the global energy crisis. Therefore, this research investigates the feasibility of automating and optimizing renewable energy generation and storage in domestic settings using EVs. This study aims to provide a sustainable alternative to conventional power generation while enhancing energy efficiency and storage capabilities.

Specific objectives include:

I. To assess the feasibility of automation and optimization of renewable domestic energy production and storage using EVs
II. To assess the economic implications of optimization and automation of renewable domestic energy supply using EVs

Determining the potential of automation and optimizing renewable energy generation and storage will be consequential in adopting EVs in domestic settings. Many families will see the need to integrate EVs into the domestic grid as an efficient approach to attain energy security. The improvement will see a net increase in the adoption of EVs based on dual applications. EV manufacturers will benefit from the adoption through increased sales of EVs.

1.5 Research questions:

I. Is automation and optimization of renewable domestic energy production and storage using EVs feasible?
II. Does automation and optimisation of renewable domestic energy production and storage using EVs reduce the cost of power and increase self-sufficiency in energy supply for households?
III. What are the environmental, grid health, and social impacts of automating and optimizing renewable domestic energy production and storage using EVs?

2 Literature review

EVs have emerged as a promising solution to reduce the energy costs and mitigate the impacts of climate change. As the world transitions towards sustainable energy systems, the adoption of EVs is expected to increase significantly in the coming years.

This literature review chapter provides an in-depth analysis of the current state of EV technology, exploring various aspects such as energy storage, power network implications, and their role of renewable energy sources. The chapter evaluate the existing literature on EVs, identifying gaps in knowledge, and proposing avenues for future research.

2.1 Uptake and energy storage using EVs

Multiple investigations show a rise in the popularity of EVs in different parts of the world. Based on a recent publication by the International Energy Agency (IEA), the sales of electric cars have increased significantly over the past decade. In 2012, up to 120,000 EVs were on roads across the globe. The agency reports that an equivalent number were sold every week in 2021 (IEA, 2022). According to Wellings et al. (2021), the number of EVs sold doubled to 6.6 million in 2021. As a result, the amount of electric cars on the roads significantly increased to 16.5million, up from 9.9Million

The regions that experienced a high increase in EVs were China, US, and Europe, and this is expected to rise in the next few years. With enhanced government support, EVs are projected to account for between 11 to 28% of the global market (Razmjoo et al. 2022).

In Europe, EVs are expected to account for at least 50% of the automobiles in the region by the year 2035 (McKinsey, 2021). The projections are based on the targeted regulatory measures intended to enhance EV uptake.

The energy storage system remains an essential component of EVs. Hasan et al. (2021) reported that EVs rely on the use of batteries for the storage of energy. EVs exist in two variants: Fully Battery Electric Vehicles (FBEV) and Hybrid Electric Vehicles (HEV). In the former, the battery must be charged from a station and provides varied mileage depending on the battery power. According to Hasan (2021), the average mileage for FBEV is between 100km and 400km. On the other hand, HEV relies on storage energy and an Internal Combustion Engine (ICE).

According to Xu et al. (2023), the EV battery is one of the potential energy storage solutions and may be applied to improve the grid's performance. Since the inception of the EV, the costs of producing have declined to translate into cost reductions in the use of the systems. Xu et al. (2023) determined that using the batteries for energy costs through enhanced grid efficiency is attainable as early as 2030. Based on this, the integration of the EV battery is the primary storage generated in domestic settings.

2.2 Implications of EVs on power networks

In the face of the increased adoption of EVs, there is a concern about a possible overload of the grid system. This necessitates considering alternative energy sources for EVs to avert adverse implications. In a Dulău and Bică (2020) study, they investigated the impacts of the projected surge in EV numbers on the grid network. From the study, the authors established that EVs have varied effects, including increased short circuit currents, voltage levels exceeding the pre-set limits, and reduced lifespan of equipment such as transformers. The study's outcome indicates that the increased power demand required to charge EVs will adversely impact the grid and lead to inefficiencies and damages.

2.3 Green/renewable energy

The experience of the energy crisis, coupled with the increased concern for environmental sustainability, has influenced a redirection of the focus of many countries towards renewable energy sources as potential solutions. Different sources of green energy, including hydropower, wind and biomass have become popular based on the need to reduce the reliance on fossil fuels (Sawin et al., 2016). These technologies substantially impact the environment by lowering greenhouse gas emissions and enhancing air and water quality. In addition, they help to provide energy security by lowering reliance on limited fossil fuel supplies (Bernai, 2013).

The difficulties in integrating sporadic renewable energy sources into the electricity system highlight the necessity for better energy storage technologies (Zakeri & Syri, 2015). Supportive legislative and regulatory frameworks are crucial for encouraging the harnessing and utilising green energy technologies (Sovacool & Dworkin, 2015). However, according to research data, investments in renewable energy have become more cost-competitive with those in conventional fossil fuels (Lazard, 2020). These investments advance sustainability and spur economic development locally and nationally (Heinberg & Fridley, 2016).

According to recent global trends, nations have established ambitious renewable energy objectives and increased their clean energy capacities (Rogelj et al., 2016). Emerging economies like China and India are critical contributors in expanding the use of renewable energy (Destek & Aslan, 2017). Renewable energy technology constantly improves efficiency and durability. (Ellabban et al., 2014).

Green and renewable energy sources have emerged as critical of these efforts worldwide to combat climate change, improve air quality, and increase energy security. Despite obstacles, a more sustainable and ecologically benign energy future is ushered through continued research, technological advancements, and supportive policies.

3 Theoretical framework and conceptual foundations

The exploration of the potential of optimisation and automation of energy generation and storage will be guided by Stern's Value-Belief-Norm (VBN) theory. The model aids in understanding the normative factors that mediate sustainable behaviour and attitudes by individuals (J.Hiratsuka et al,2017). Lind et al. (2015) indicate that the framework integrates norm activation theory, new environmental paradigm theory and value theory to explain the decision by individuals to adopt sustainable approaches to energy generation and storage. Awais et al. (2022) applied the VBN framework to explore the drive for people to adopt solar energy as a pro-environmental behaviour. In the context of the proposed study, individuals' values, beliefs, and norms are integral in shaping the desire to automate and optimise energy generation and storage through integrating EVs into the domestic grid system.

The value component of the model relates to a desirable trans-situational goal that is important to individuals and acts as a guiding principle in adopting a particular behaviour (Lind et al., 2015). The expected value derived from the implementation of the improvement is expected to be instrumental in adopting technologies that automate and optimise the use of EVs in domestic settings.

The new environmental paradigm mainly relates to the sustainability concerns informed by the implications of overreliance on natural gas to generate power for the grid and a further escalation of this overreliance from the potential grid overload by EVs. The automated and optimised use of EVs will be vital in reducing the environmental impacts, primarily through reducing the carbon footprint associated with energy generation and usage. Through the influence of the value and new ecological paradigm, the norm of relying on EVs as a storage method for domestic energy will be experienced in the population. While VNB has been extensively applied in environmental sustainability, the framework can be replicated to comprehend the social and economic impacts of the proposed EV application in domestic energy systems.

This study embraces fundamental aspects of energy management, integrating renewable energy, electric vehicle technology, and strategies for optimisation. The framework sets the foundation for exploring how domestic renewable energy production, energy storage, and electric vehicle utilisation can work together to create a more sustainable and efficient energy ecosystem.

3.1 Energy management and optimization

Energy management efficiency is critical for integrating renewable energy with EVs, enhancing energy efficiency, and ensuring resource optimisation. Intelligent energy management easily incorporates EVs by synchronising charging to energy demand and grid conditions. It also balances energy sources, increasing grid stability. Excess renewable energy is stored in EVs to ensure maximum availability during periods of low production. Furthermore, reduced grid reliance and potential energy sales result in financial savings (B.Burmahl,2022).

Decisions on energy management are inextricably tied to Stern's VBN Theory because they reflect individuals' values and beliefs about environmental sustainability and energy conservation. When consumers emphasise efficient energy consumption, renewable energy integration, and grid stability, they connect their decisions with Stern's theory's principles of environmental responsibility and conservation. Furthermore, energy management strategies that promote cost savings and reduce dependency on fossil fuels align with social ideals of sustainability and economic prudence. As a result, individual values and beliefs impact energy management decisions, ultimately contributing to the adoption of sustainable practices by Stern's VBN Theory (Elkazaz et al., 2019).

3.2 Renewable energy integration

Residential solar energy integration is critical to modern energy management and optimisation. As homeowners' concerns about sustainability, energy efficiency, and environmental responsibility rise, they increasingly turn to solar power to reduce their carbon footprint and energy expenditures. Integrating solar energy into home energy management systems improves energy efficiency. It adheres to the principles of Stern's Value-belief-norm Theory, which holds that people's values and beliefs influence their decisions about environmental sustainability and energy conservation. When homeowners choose to use solar energy, they are motivated in part by a conviction for responsible environmental practices and a desire to conserve energy resources, which contributes to the adoption of sustainable energy management techniques (Mwasilu et al., 2014)

3.3 Electric vehicle technology and wireless charging using machine vision and machine learning

The development of electric vehicle (EV) technology signals a fundamental shift in the automobile industry toward environmentally friendly and sustainable transportation.

EVs rely on rechargeable batteries resulting in zero exhaust emissions and lower greenhouse gas emissions contrary to conventional internal combustion engines. EVs have several advantages, including lower running costs, less air pollution, and less reliance on fossil fuels (Tseng et al., 2013).

On the flip side, several challenges that impact their widespread adoption can be inferred from the abovementioned benefits. Such challenges include efficient and convenient charging systems and the long-term sustainability of the charging load on the primary grid. This poses an overload risk in a future scenario where most of the population converts to using EVs. Traditional plug-in charging technologies necessitate physical connections, restricting charging networks' flexibility and scalability. To overcome this issue, incorporating machine vision and machine learning technologies into EV technology has grown in popularity (Panossian, Muratori et al., 2022).

Machine vision is perceiving and interpreting visual information using cameras and image processing algorithms. Machine vision is critical in the automated charging operations of EVs. Majority of the EVs outfitted with cameras and sensors can find charging stations, correctly line themselves with charging interfaces, and establish a secure connection without human involvement. This automated process enhances the charging experience for EV owners while increasing EVs' applicability in Smart applications (Talaat et al., 2020).

Machine learning algorithms can improve the effectiveness of wireless charging, an innovative strategy for EVs that eliminates the need for tangible wiring and connectors. This is attained by constantly modifying charging parameters founded on real-time data. These algorithms can predict suitable charging times, modulate power levels, and even integrate changes in ambient variables. This versatility not only provides faster and more effective charging but also prolongs the lifespan of Electric Vehicle (EV) batteries, making them a dependable energy storage solution (Mazhar, Asif, Malik, Nadeem, Haq, Iqbal, ... & Ashraf, 2023).

Machine vision and machine learning integration in Electric Vehicle (EV) technology optimises every aspect of user experience. EVs can interface with charging infrastructure, analyse the condition of charging stations, and offer users real-time feedback. Machine learning algorithms can also predict battery degeneration, allowing consumers to make more informed maintenance and replacement decisions. As a result, the Electric Vehicle (EV) is an excellent choice for storage in an intelligent energy ecosystem (Qaisar & Alyamani, 2022).

In addition, the improved user experience is linked to Stern's Value-Belief-Norm Theory, which underpins the adoption and acceptance of Electric Vehicle (EV) technology and its integration with advanced systems such as machine vision and machine learning. When people perceive EVs to reduce environmental harm and promote sustainability, the values and beliefs that impact their attitudes and behaviours toward environmental sustainability and energy conservation can be fostered. Machine vision and machine learning increase the appeal of EVs by making charging more convenient and efficient, facilitating the adoption of an intelligent energy ecosystem (Alan, 2016).

3.4 Smart grid and automation

Automation and the smart grid are terms used to describe cutting-edge technical systems and procedures used to manage electricity production, distribution, and consumption. These systems combine digital connectivity, data analytics, and automation to improve electrical grids' efficiency, dependability, and sustainability. Real-time monitoring, control, and optimisation of energy resources are rendered possible by smart grids, while automation streamlines processes and minimises human involvement. Collectively, they advance sustainability of the environment and ensure enhanced reliability of energy supply (Bayindir et al., 2016).

The automation on technologies are fundamental to the transformation of home energy management. This investigation aims to develop an intelligent and sustainable energy environment for houses by utilising the potential of EVs and green energy sources. Smart grid technologies, which enable live tracking, control, and optimisation of renewable energy production and consumption, are at the vanguard of this revolution. Smart Grids gather information on energy generation from solar panels and wind turbines using cutting-edge sensors and communication networks. After processing this data using automation algorithms and machine learning approaches, accurate projections of energy availability are produced (Gandoman et al., 2018).

Electric cars are used in this scheme as dynamic energy storage devices. In order to minimise energy waste and maximise self-consumption, excess renewable energy can be generated and stored in EV batteries. Automated algorithms to regulate batteries in EVs, warranting that power is accessible even when demand is at its highest. These benefits of integration are extensive. It improves energy efficiency in the first place by lowering dependency on the primary grid and reducing energy losses during transmission. Balancing energy supply and demand in real time also helps maintain grid stability. Additionally, it supports using clean, renewable energy sources and lowers greenhouse gas emissions, which are sustainability tenets (Rahbari et al., 2017).

The application of Smart Grid and Automation technologies in residential energy management is congruent with Stern's Value-Belief-Norm Theory, which emphasises the importance of individual values and beliefs on environmental responsibility and conservation. In this context, adopting Smart Grid and Automation technologies displays a commitment to environmental sustainability and energy conservation. Individuals who value energy efficiency, renewable energy integration, and grid stability are putting these ideas into practice by installing these technologies. Homeowners can lessen their reliance on fossils energy sources leading to a reduction in greenhouse emissions, a key component of environmental responsibility, by utilising renewable energy sources and EVs to build an intelligent and sustainable energy ecosystem. This congruence of human values with environmentally friendly behaviours shows how Stern's theory influences choices about energy management and the adoption of cleaner, more effective technology (Mesarić et al., 2017).

3.5 Optimization strategies

The efficient integration of domestic renewable energy production and storage with EVs depends heavily on optimisation algorithms. Maximising the effectiveness and dependability of these systems becomes essential as the need for sustainable energy solutions rises. This study focuses on using EVs as flexible energy storage systems and maximising the potential of renewable energy sources, notably solar panels. The backbone of this integration is optimisation strategies, which ensure that energy output and consumption are precisely calibrated for sustainability and grid stability (Melhem et al., 2017).

The use of real-time demand-response systems is a crucial component of optimisation. By prioritising energy consumption during periods of high demand and redirecting extra energy to electric vehicle (EV) batteries when supply exceeds need, these processes allow the system to adjust to shifting energy needs. By regularly evaluating figures from numerous sources, such as weather forecasts, trends of energy consumption, and electric vehicle (EV) charging behaviour, machine learning algorithms, such as reinforcement learning and predictive analytics, increase the precision of these methods (Rawat, Niazi, Gupta, & Sharma, 2019).

The management of electric vehicle (EV) charging and discharging is also included in optimisation. Intelligent charging algorithms identify the most economical and grid-friendly charging schedules by considering energy cost, time of use, and grid conditions.EVs are simultaneously used as mobile energy reservoirs, enabling load balancing and peak shaving inside the domestic energy ecosystem (Alonso et al., 2014).

The use of optimisation techniques ensures several advantages. First, it considerably improves energy efficiency by lessening dependency on the primary grid and reducing energy losses during transmission. Second, balancing energy demand and supply in real-time lessens the possibility of blackouts and brownouts. Finally, it supports using clean, renewable energy sources and lowers greenhouse gas emissions, which aligns with sustainability ideals (Tan et al., 2016).

This method of automation and optimisation offers a path forward in the direction of a home energy future that is more resilient and sustainable. It is inextricably connected to Stern's VBN theory, which emphasises the values of environmental stewardship and conservation. Integrating these sustainability ideals into daily life is shown in the optimisation of home energy generation and storage using EVs, which prioritises energy efficiency, grid stability, and the reduction of greenhouse gas emissions. This link between personal values, beliefs, and sustainable energy habits highlights how crucial automation and optimisation are to attaining a future that is more ecologically aware and energy efficient (Van et al., 2016).

4 Methodology

4.1 Research design - paradigm and strategy

The research used a mixed-methods paradigm, combining quantitative and qualitative research. The quantitative approach was rooted in the need for collection of empirical data gathering and statistical analyses to assess the effectiveness of the proposed automation and optimisation strategies to provide objective and measurable insights into the effect of renewable energy incorporation and EV utilisation on domestic energy production and storage. The qualitative aspect was used to focus on understanding the underlying subjective meanings, behaviours, and experiences of individuals regarding the proposed solution (Khaldi, 2017)

The research strategy predominantly employed content analysis, observations, structured surveys, statistical analysis of structured data, experiments, secondary data analysis, regression analysis, and open-ended questions (Khaldi, 2017). Accurate world data from renewable sources of energy, EV charging patterns, and consumption was utilised to develop and validate the automation and optimisation models. The approach closely mimicked real-life scenarios, providing practical insights for tangible recommendations.

4.2 Data collection and preprocessing

The collection of primary data from sensors, meters, and data acquisition systems within test households was constrained due to the unavailability of suitable test premises. Consequently, the research primarily relied on secondary data from existing databases and relevant literature on renewable energy production and electric vehicle (EV) charging.

All data for this study was obtained through a comprehensive review of relevant literature, including peer-reviewed sources, and from established databases and repositories. Questionnaires were also used to collect public views on the proposed system. This systematic process involved identifying, selecting, and synthesising pertinent information and findings. The utilisation of secondary data sources facilitated a comprehensive exploration of the research area, providing access to a wealth of historical and contemporary information for analysis and interpretation.

In adherence to ethical standards and data privacy, informed consent was obtained from participants, providing a clear understanding of the study's purpose and data usage. Privacy safeguards included anonymising or de-identifying sensitive data and implementing data security measures like encryption and secure storage. Research integrity was maintained through accurate reporting, avoidance of data manipulation, and a commitment to transparency. Respect for data ownership rights and adherence to usage agreements were paramount. Additionally, full compliance with relevant regulations and ethical guidelines, including obtaining necessary approvals, was ensured, primarily focusing on the safety of all parties involved (Stahl et al., 2013).

The data obtained from the relevant sources underwent preprocessing procedures for cleaning, validation, and transformation into formats reliable for analysis. This was done as a critical step in ensuring the reliability and accuracy of the findings.

5 Implementation

An implementation approach will be discussed in this chapter, which takes into account a variety of aspects of the production, storage, and management of energy. An energy production automation and storage integration framework that outlines the seamless integration of automated energy production systems. Energy Cycling for EVs will also be explored as it utilizes machine learning and machine vision techniques to optimize the management of energy. The technical details of matrix charging which provides a thorough analysis of the charging system, its design, installation and functional steps will also be highlighted. To evaluate the system's performance, the chapter presents a Performance

Evaluation Approach, which employs rigorous metrics to assess the system's effectiveness.

5.1 Energy production automation and storage integration framework

A solid and sophisticated Energy Production Automation and Storage Integration Framework is essential in maximising domestic renewable energy production and storage by integrating EVs. The suggested system is supported by this framework, which enables the smooth orchestration of numerous components. Below is a description of the main features of the framework, along with its core system and precise implementation (Prado et al., 2019).

I. Solar panel sizing process

The efficient home use of solar energy, mainly through solar PhotoVoltaic (PV) arrays, lies at the framework's core. The focus is gathering sunlight and transforming it into electrical energy for home usage. Solar panels are carefully placed on rooftops or other designated locations to get the most sun exposure. The panels are linked to grid-tied inverters to transform the Direct Current (DC) electricity generated by the panels into Alternating Current (AC) power compatible with the grid. Irradiance sensors and power meters, among other real-time monitoring tools, guarantee efficient energy production and grid synchronisation. To arrange solar panels optimally and maximise sunlight absorption, the irradiance sensors evaluate the radiant energy received from the sun. (Nuhin et al, 2022).

A vital component of the Energy Production Automation and Storage Integration Framework is the size of the solar panels. Effectively harnessing solar energy at the residential level entails a thorough assessment of the quantity and capacity of solar panels. The sizing process ensures that the system produces the ideal electricity to satisfy the household's energy needs. Solar panel sizing follows the steps elucidated below (Al-Shamani et al., 2015)

II. Solar insolation assessment

Analysing the solar insolation at the installation site is the first stage in sizing solar panels. The amount of solar energy received per square meter is called solar insolation. This assessment provides data on the typical daily and seasonal sun irradiation. In order to determine the viability of such a system, solar insolation data should be gathered utilising online tools that offer maps of the sun's radiation specific to the installation area. Both satellite-based solar radiation datasets and observations of solar radiation from the ground are examples of these data sources. The National Renewable Energy Laboratory's (NREL) Solar Resource Data, the European Space Agency's (ESA) Climate Change Initiative - Solar Surface Radiation, and the Photovoltaic Geographical Information (PVGIS) System were identified as key resources that can efficiently support this course (Odhiambo et al., 2020).

III. Load analysis

Load analysis encompasses the evaluation of the household's daily energy usage. This assessment aids in gaining insights into the energy requirements the solar panels must fulfil. A comprehensive load analysis entails collecting data about all energy-consuming appliances and devices, estimating their daily usage, and computing the overall daily energy consumption. The formula below, represented as equation 1, can be employed to ascertain the energy consumption, thereby indicating the energy needs of the household(McLoughlin, Duffy, & Conlon, 2013):

Equation 1.Daily Energy Consumption

$$\text{Daily Energy Consumption (kWh/day)} = \Sigma\,(\text{Appliance Power (kW)} \times \text{Usage Time (hours)} \times \text{Load Factor})$$

IV. System sizing calculation/solar panels' capacity (kWp)

The system sizing calculation integrates solar insolation data and load analysis to determine the ideal number and capacity of solar panels, accounting for panel efficiency, shading, and seasonal fluctuations. By utilising information from the solar insolation assessment and load analysis, mathematical calculations establish the necessary size of the solar panel array, considering the panel's rated capacity, efficiency, and local climate conditions. Equation 2 below represents the formula for determining the required solar panel capacity based on the daily energy consumption, solar insolation, and panel efficiency(Benchrifa & Mabrouki, 2022):

Equation 2.Solar panel capacity

Solar Panel Capacity (kWp) = Daily Energy Consumption (kWh/day) / (Solar Insolation (kWh/m^2/day) × Solar Panel Efficiency)

It should incorporate variables such as climate variations and system losses to customise this formula for specific regional requirements. Local climate conditions and solar insolation fluctuations are of utmost relevance. The precision of daily solar insolation estimates can be enhanced by utilising historical insolation data for the area. Seasonal fluctuations are best addressed by averaging insolation data across different seasons. Realistic solar panel efficiency can be attained by adjusting the efficiency factor to align with actual performance. This alignment can be based on manufacturer data and empirical location-specific data for accurate efficiency estimations (Chikate et al., 2015).

V. Storage battery selection and sizing

The energy storage framework's crucial stage is sizing the storage batteries. In order to effectively store extra energy and maintain a reliable power supply during poor solar generation, the right size and number of batteries must be chosen (Valencia et al., 2021).

The initial consideration is the battery selection, accounting for capacity, efficiency, cycle life, size, maintenance requirements, and environmental impact. Lithium-ion batteries were chosen as the preferred option in the proposed system due to their higher efficiency, longer operational lifespan, and reduced maintenance needs. These batteries excel at efficient energy storage and release with minimal losses and can endure more charge-discharge cycles over their lifetime. Lithium-ion batteries are also typically more compact and lightweight than lead-acid batteries, optimising space utilisation. Furthermore, they are environmentally friendlier, containing fewer hazardous materials than lead-acid batteries (Keshan et al., 2016).

VI. Energy storage requirements (kWh)

Using the daily patterns of energy generation and consumption, energy storage needs can be calculated, along with the desired depth of discharge (DoD) required to increase battery life.

The daily energy storage requirements are quantified mathematically, considering corrections for efficiency losses and the DoDs that preserves battery health. The formula for energy storage requirement is represented by equation 3 below (Olaofe & Folly, 2012):

Equation 3. Solar panel capacity

$$\text{Solar Panel Capacity (kWp)} = \text{Daily Energy Consumption (kWh/day)} / (\text{Solar Insolation (kWh/m}^2\text{/day)} \times \text{Solar Panel Efficiency})$$

VII. Determining the battery capacity (kWh)

Following the battery selection and the assessment of energy storage needs, the subsequent phase involves sizing the battery bank. This process considers factors such as the battery's capacity, voltage, and the quantity of batteries required. Precise mathematical calculations are then carried out to ascertain the appropriate size and arrangement of the battery bank. Equation 4, as presented below, takes into consideration the energy storage demands, efficiency losses, and the preferred autonomy period in hours (Jacob et al., 2018):

Equation 4. Battery Capacity

Battery Capacity (kWh) = Energy Storage Requirements (kWh) / (Battery Efficiency) + (Daily Energy Consumption (kWh/day) - Daily Energy Generation (kWh/day)) × Autonomy (hours)

VIII. Automation implementation of the core system

In the proposed framework, automation shall serve as the central hub, overseeing real-time data analytics, demand response mechanisms, and the control of distributed energy resources (DERs) to enable effective energy management (Rathor & Saxena, 2020). The approach adopted involves the seamless integration of Programmable Logic Controllers (PLCs) and the infrastructure of the Industrial Internet of Things (IIoT), connecting with sensors, actuators, and the central grid without interruption (Misra et al., 2021).

An advanced metering infrastructure (AMI) is seamlessly incorporated into the system to facilitate real-time energy consumption monitoring. In parallel, strategically positioned grid sensors gather data on grid conditions and establish communication with the central grid. The integration extends to energy storage systems (ESS), including lithium-ion and electric vehicle (EV) batteries. These batteries serve as reservoirs for storing surplus energy during periods of excess supply. Additionally, wireless Electric Vehicle Charging Stations (EVCS) are installed to enable the charging and use EVs and the grid (Alsharif et al., 2021).

The Programmable Logic Controllers (PLCs), leveraging their deterministic control capabilities, are the principal controllers for real-time system monitoring and administration. Their roles encompass ensuring uninterrupted grid connectivity, overseeing renewable energy generation, directing energy storage systems, and streamlining the integration of EVs (Zafar et al., 2020).

The IIoT infrastructure complements the functionality of Programmable Logic Controllers (PLCs) by gathering diverse data from sensors, actuators, and devices. This data is subjected to advanced analytics and machine learning algorithms for in-depth analysis, enabling adaptive control and predictive maintenance approaches. These findings improve energy efficiency grid stability and optimise resource allocation on a broader scale (Pivoto et al., 2021).

5.2 Energy cycling for electric vehicles: A machine learning and machine vision approach.

To implement an optimised energy cycling system for EVs seamlessly integrated into the broader Energy Production Automation and Storage Integration Framework, a comprehensive approach is essential, leveraging the potential of Machine Learning (ML) and Machine Vision (MV). The approach guarantees efficient utilisation of renewable energy sources, grid interaction, and dependable operation of EVs as energy storage assets, thereby promoting sustainable domestic energy management (Wu et al., 2022). The implementation proceeds as follows:

I. Gathering and incorporating data.

The initial stage of the proposed system entails the comprehensive gathering of data from numerous sources, including solar panels, records of household energy use, and electric vehicle (EV)-related metrics, using the IIOT infrastructure. The research's base is the compiled data, which provides a comprehensive overview of the home energy ecology. This gathered data is subjected to data preparation procedures as a crucial step to guarantee the data is clean, accurate, and standardised, supporting high-quality inputs. The objective is to produce a reliable dataset that can be relied upon for subsequent analysis (Bin Mofidul et al., 2022).

II. Development of machine learning models

The proposed system leverages ML to construct predictive models to anticipate household energy demand, solar energy generation, and Electric Vehicle (EV) usage patterns. These predictive models represent critical elements within the system, enabling the formulation of data-driven insights to support informed decision-making (Sharifzadeh et al., 2019).

The process commences by carefully choosing and deploying Machine Learning algorithms tailored to the project's unique demands. Given that the system primarily deals with time series data, the selected Machine Learning models should demonstrate proficiency in effectively managing this data format. In this particular context, the suggested Machine Learning models include Long Short-Term Memory (LSTM) Networks, Seasonal Autoregressive Integrated Moving Average (SARIMA), and Gated Recurrent Units (GRUs) – (Arun Kumar et al., 2022)

The approach employs an ensemble method, which entails training all three models and utilising their outputs to train a meta-model. This ensemble method approach aims to mitigate overfitting, enhance model stability, and augment prediction accuracy by encompassing a range of patterns derived from the diverse models. Both historical data and real-time inputs are crucial in the model training process. As the algorithms are fed with data, they acquire knowledge of patterns and interconnections, leading to precise predictions across various aspects of the energy system (Gastinger et al., 2021)

III. Energy forecasting

The subsequent step in the quest for an optimised energy system is energy prediction. The previously formulated predictive models are amalgamated in this phase to foretell energy generation, consumption, and potential excess. This amalgamation is the foundation of the system's capacity to enhance energy management. Machine Learning assumes a pivotal role in the demand-side management strategy. The system's proficiency in forecasting the optimal timing and manner for charging or discharging EVs stands out. This predictive proficiency ensures the harmonisation of EV operations with the overarching objectives of energy efficiency and sustainability (Aslam et al., 2020).

IV. Optimized matrix charging infrastructure for electric vehicle energy cycling

In order to enhance the interaction between EVs and a larger Renewable Energy Management System, this section focuses on integrating Machine Vision technologies for wireless energy cycling. The key goals are to increase energy efficiency and sustainability while achieving optimum wireless charging and discharging of EVs in a smart grid setting (Talaat et al., 2020).

Matrix charging, a cutting-edge technology that allows EVs to be charged and discharged efficiently and intelligently, was preferred as the best option for the proposed energy system. Its strength lies in integrating Machine Vision for instantaneous EV recognition, Machine Learning models for effective demand-side control, and seamlessly merging with sustainable energy sources to establish a well-rounded solution for enhancing Electric Vehicle (EV) energy cycling (Liu et al., 2018).

This comprehensive methodology nurtures a dynamic and intelligent energy management system that delivers advantages to EV owners and the environment. By harnessing these technologies and insights derived from data analysis, a holistic depiction of how Matrix Charging improves energy cycling for EVs, thereby promoting sustainability and the efficiency of a household energy management system, is achieved (Liu et al., 2018).

5.3 Technical aspects of matrix charging .

I. Real-time recognition of electric vehicles using machine vision

Matrix Charging utilises state-of-the-art Machine Vision technology to achieve real-time EV detection within a residential environment. The system is proficient in identifying the presence of nearby EVs by employing an array of strategically placed cameras and advanced image processing techniques, including object detection. These strategically positioned cameras provide comprehensive coverage, ensuring that no motion of EVs remains unobserved. Through precise monitoring and control of Electric Vehicles' charging and discharging activities facilitated by these real-time identification capabilities, the system can swiftly adapt to alterations in the EV environment (Zhang et al., 2022).

II. Utilizing machine learning models to enhance demand-side control

Matrix Charging includes an essential component of advanced Machine Learning models. These models are critical in managing the demand side of the system, facilitating the precise prediction of the optimal charging or discharging times for EVs. The Machine Learning algorithms collaborate with various data inputs, encompassing historical and real-time data, to understand intricate patterns and relationships. Consequently, the system can accurately foresee energy requirements and efficiently harmonise them with energy availability, demand fluctuations, and sustainability objectives. This predictive capability proves invaluable in circumventing peak demand periods and enhancing the utilisation of sustainable energy sources (Antonopoulos et al., 2020)

III. Seamless integration with sustainable energy sources

Matrix Charging effortlessly harmonises with sustainable energy sources, with a primary focus on renewable energy generation, to guarantee the operation of an effective and environmentally conscious energy management system. The system is strategically engineered to leverage the potential of sustainable sources like solar and wind energy. Through establishing robust connectivity with these energy sources, Matrix Charging fine-tunes the scheduling of Electric Vehicle (EV) charging and discharging. It places a significant emphasis on prioritising using clean and eco-friendly energy generation, thereby diminishing dependence on conventional, non-renewable resources. This integration actively advocates for sustainability, plays a pivotal role in reducing the carbon footprint associated with domestic energy systems and actively contributes to the proficient management of EV energy cycling (Venugopal et al, 2018).

IV. Optimized user experience, strengthened security, and continuous improvement

The user-friendly interface of the Matrix Charging system ensures smooth interactions with the system and gives owners of EVs control over the charging and discharging procedures. Strong cybersecurity measures are also included to enhance the system's security and dependability and protect user data and system integrity. The system constantly aspires to better itself as a fundamental aspect of its design. It improves the predictive accuracy of its machine learning models and solicits user feedback to pinpoint areas for optimisation, allowing it to develop and adhere to changing performance requirements (Ali, Hasan et al.,2021).

V. Matrix charging mechanism demystified

Matrix charging employs electromagnetic induction for wirelessly transmitting electric power from the embedded charging infrastructure in the roadway or parking area to an electric vehicle (EV), eliminating the need for physical connections. (Zhou et al., 2021).

5.4 The installation and functional steps of matrix charging

I. Installation of the charging plates

The seamless procedure is initiated by installing charging plates, which act as the main coil for electromagnetic induction. These plates are strategically positioned in designated parking zones and are crucial in wirelessly delivering power to the electric vehicle (EV). The installation typically entails securely anchoring the plates to the ground, ensuring precise alignment with the EV's receiving equipment. These charging plates function as the primary interface for power transfer to the EV during the charging process (Zhou et al., 2021).

Machine Vision technology is utilised to recognise instantly and position EVs in this context. It facilitates precise monitoring and control of the bidirectional energy flow in EVs through real-time identification capabilities, ensuring the system swiftly adapts to changes in the EV environment (Zhou et al., 2021).

Conversely, in this phase, Machine Learning Models are integrated to enhance demand-side control. These models forecast EVs' optimal charging or discharging times, ensuring synchronisation with energy availability, demand, and sustainability objectives. Machine Learning algorithms collaborate with input data, encompassing historical and real-time information, to discern intricate patterns and relationships, enabling precise anticipation of energy requirements and efficient synchronisation with renewable energy sources (Zhou et al., 2021).

II. Electric vehicle integration with receiver technology

A compatible receiver, or secondary coil, is installed on the electric vehicle (EV), serving as the point of contact with the charging plates and facilitating wireless power transfer. It includes specialised hardware and sensors to achieve precise alignment and energy transfer. When the Electric car (EV) is parked within the designated area, this equipment wirelessly captures electricity from the charging plates (Zhou et al., 2021).

III. Automated wireless power transfer

Wireless power transmission serves as the fundamental building block of the Matrix Charging infrastructure. It hinges on the technology of resonant inductive coupling, enabling energy transmission from the charging plates to the Electric Vehicle's (EV) receiving apparatus without the need for physical connections. An alternating current (AC) courses through the primary coil, generating a magnetic field. This magnetic field, in turn, induces an electrical current within the secondary coil of the EV, which is harnessed to charge the EV's battery. The effectiveness of this energy transfer is at its peak when the primary and secondary coils are precisely aligned and meticulously tuned to the identical resonant frequency. This wireless transfer method features notable efficiency, providing secure and contactless charging. This highly efficient and dependable energy transfer procedure operates completely automated, continuously monitoring and fine-tuning the power supply to meet specific requirements. Its primary focus is on sustainability and the utilisation of clean energy, cohesively synchronising the charging cycle with renewable energy sources. (Zhou et al., 2021).

5.5 Rationale for choosing matrix charging technology

Matrix Charging is optimal for wireless energy transfer. It is highly efficient, saving a lot of energy during the transfer. This not only helps conserve energy but also makes the whole system work better. Plus, it is convenient – no need for plug-in cables, making it perfect for self-driving cars. With Matrix Charging, drivers don't have to worry about handling the charging process. Another notable aspect is that it reduces wear and tear on both vehicles and charging spots by getting rid of physical connectors. It's flexible, too, with charging plates that can go in driveways, parking lots, or walls, making it easy to set up Electric

Vehicle (EV) charging. Matrix Charging is smart about space – it fits those charging plates into existing structures, making the charging process efficient. (Gu et al., 2020).

5.6 System optimization aspects

Optimising the proposed energy ecosystem's processes for both energy control and performance evaluation involves combining IIIoT, PLCs, Machine Learning, and Machine Vision in the quest for an energy system that includes Matrix Charging for EVs. A strong framework integrating real-time control, data analytics, and predictive capabilities is achieved. The smooth interaction between these systems delivers several benefits, as discussed in this section (Elangovan,2021):

The IIoT gateways incorporated into PLCs allow them to combine data collected from various sensors and equipment used in the energy ecosystem. This centralised data centre is the core of real-time energy consumption optimisation and predictive maintenance (Elangovan,2021).

Utilising the IIoT platform, the data collected from PLCs is evaluated through an analysis that reveals invaluable insights, finds anomalies, and pinpoints possible areas for energy system optimisation (Elangovan,2021).

The knowledge gained from IIoT analytics actively directs PLCs control techniques, enabling real-time adjustments to optimise energy management more efficiently (Elangovan,2021).

As a proactive aspect of the system, predictive maintenance uses the IIoT to operate as a vigilant overseer, always checking the condition of PLC components and anticipating maintenance needs to prevent system outages (Elangovan,2021).

Modern Matrix Charging Technology is implemented with the IIoT-PLC fusion to enable wireless energy transmission to and from EVs without needing physical connections. This idea seamlessly fits in with the main goals of sustainability, efficiency, and ease of use (Elangovan,2021).

Machine Learning Models for Demand-Side Control is the suggested solution's core. These algorithms use historical and current data to estimate the most appropriate times to charge and discharge EVs. These models effectively match energy demand with supply, sustainability goals, and decreasing peak demand periods by unravelling complex energy consumption patterns and relationships (Elangovan,2021).

The suggested solution also incorporates Real-Time EV Recognition using Machine Vision Technology. This system uses well-placed cameras and sophisticated image-processing algorithms to instantaneously detect EVs in the household setting. With their thorough coverage of the authorised areas, these cameras enable accurate monitoring and management of Electric Vehicle (EV) charging and discharging activities. Due to its real-time identifying capabilities, this technology can quickly adapt to changing Electric Vehicle (EV) situations (Elangovan,2021).

5.7 Performance evaluation approach

The evaluation of the proposed systems involves a comprehensive methodology. Initially, the system systematically collects relevant data on energy consumption, Electric Vehicle (EV) charging, and the integration of renewable energy, serving as the foundation for performance assessment. Subsequently, Machine Learning models meticulously analyze the acquired data to identify trends, patterns, and potential areas for improvement, ensuring a continuous enhancement of the system. It becomes imperative to establish Key

Performance Indicators (KPIs) to measure the system's performance, encompassing aspects such as overall reliability, sustainability, and energy efficiency. Regular audits of the proposed system are then conducted to assess its effectiveness against the established KPIs, with the results of these audits meticulously documented to drive continuous improvements (Elangovan, 2021).

5.8 Ethical considerations of the proposed system

Various ethical concerns were considered in the study, and appropriate adaptations were implemented. Before the study, the participants were briefed on different aspects of the study to facilitate the making of informed choices to participate in the survey. In addition, the participation was voluntary. This ensured that the participants willingly engaged in the investigation. Another critical issue was the protection of the participant privacy. The participants were required to fill out the survey anonymously. The approach ensured that participants could not be identified based on shared information

6 Presentation and analysis of results

In investigating the feasibility, automation, and optimisation of domestic energy production and storage using electric vehicles, as well as the economic implications, a survey focused on the perception of individuals from different parts of the world was conducted. The questionnaire was administered over the Internet based on the convenience of reaching participants from different parts of the world. A total of 70 questionnaires were sent to participants. Table 1 and 2 shows the distribution of participants by location and gender/age.

Out of this, 56 responses were received, translating into a response rate of 80%

Table 1. The Distribution of Participants by location and gender

Region	**Female**	**Male**	**Totals**
Europe	13	15	28
Africa	2	1	3
Asia	1	2	3
America	19	2	21
Australia		1	1
Total	36	20	56

Table 2. The Distribution of participants by location and age

Age	**Female**	**Male**	**Total**
18-30 years	10	5	15
31-40 years	17	10	27
41-50 years	6	3	9

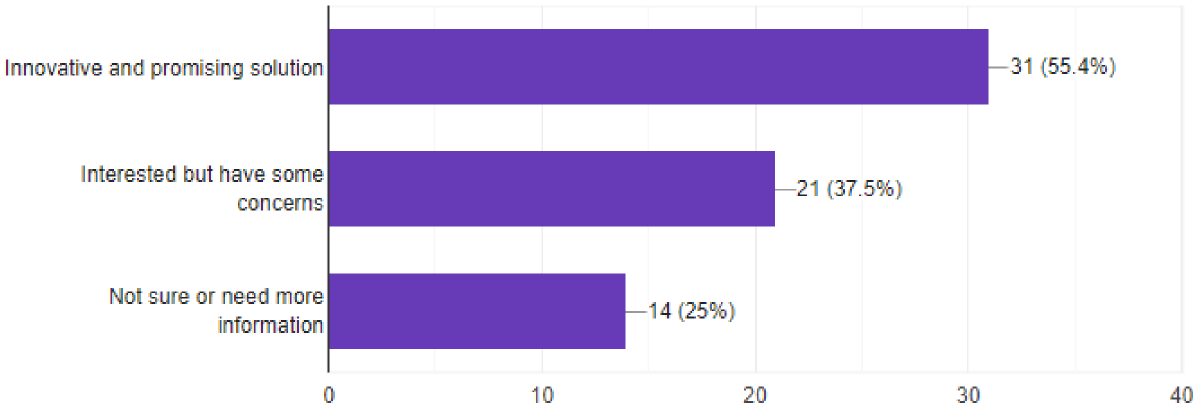
Over 50 years	3	2	5
Total	36	20	56

Based on the data collected from the survey, the uptake of electric cars remains low in different parts of the world. Most participants used cars driven by fossil fuels, with petrol and diesel accounting for 52.8% and 13.5%, respectively. Electric and hybrid cars accounted for 5.8% and 3.8%, respectively, while 23.1% of the participants reported no vehicle ownership. Despite the low uptake of electric vehicles, most participants (67.9%) reported being aware of using electric vehicles for storage and management of renewable energy in domestic settings.

For domestic energy, the survey established that most of the participants (87.5%), 49 respondents, relied on electricity as the primary source. Natural gas and solar panels accounted for 7.1% and 5.4%, which is 4 and 3 respondents, respectively. The study indicates an overreliance on the national grid for power access in most domestic settings in different parts of the world. The energy cost also varies significantly based on the information shared by participants in the survey. Most households pay between $500 and $1000 in energy bills annually.

The study explored the participants' perceptions of using electric vehicles to store the excess renewable energy households produce. A majority of the participants reported that the approach is an innovative and promising solution to addressing the energy problem faced by households. The figure below presents a summary of the responses of the participants in the study.

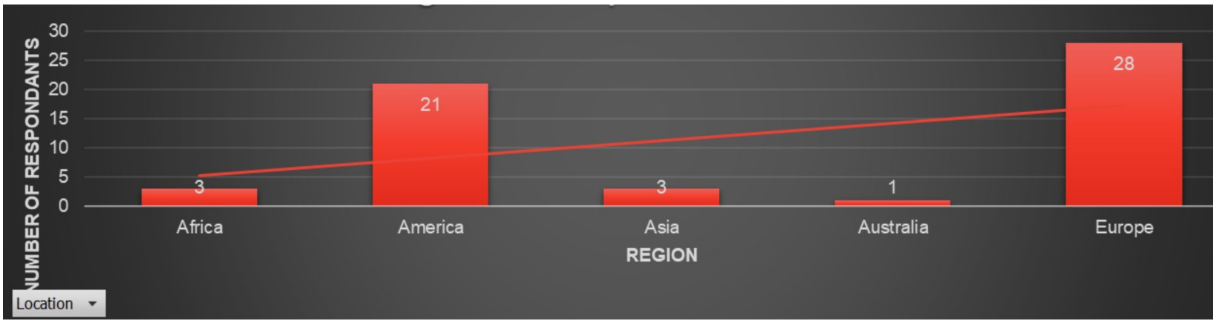
Figure 1. Perception of Participants on the Use of EVs to store Renewable energy for domestic use



A majority of the participants in the study (61%) considered automation and optimisation of energy production and storage using electric vehicles to have the potential to benefit homeowners and the environment.

The figure below shows the number of respondents from different regions who consider the automation and optimisation of energy production and storage using electric cars as beneficial in addressing the energy problem.

Figure 2. Proportion of the participants who perceive the system as beneficial by region.



However, the participants identified challenges that may limit the system's adoption in domestic settings. The high initial cost was cited as the main challenge that may affect the implementation of the system to produce and store renewable energy using electric vehicles. Up to 83.3%% of the participants expressed concerns about installing the system's initial cost. Environmental concerns related to battery manufacture (37.5%) and limited availability of electric vehicles (30.4%) also emerged as a key concern among the participants in the study.

Table 3:Distribution of participants who would consider adopting the proposed system.

Would you consider adopting such a system in your own home for renewable energy storage and management	COUNTA of Locatio
No	3.64%
Not sure	38.18%
Yes	58.18%
Grand Total	**100.00%**

Despite the concerns about the implementation of the system, a majority of the participants (58.18%) considered adopting the system to improve energy reliability in domestic settings. The positive view of automation and optimisation of energy storage using electric vehicles by households is attributable to the positive impacts of the system on the cost of energy and the environment. The table above represents the breakdown of the same.

6.1 Analysis of results

The results from the study provides insights into the feasibility of the automation and optimisation of renewable energy production and storage in domestic settings. Based on the survey outcomes, most participants rely on cars that use fossil fuels for communication, with petrol and diesel being cited as the most common energy sources for cars. In the population surveyed, the uptake of electric vehicles remains low. The low uptake of electric cars can be contextualised with the findings of previous investigations. Different barriers discourage users from the purchase of electric vehicles. One of the primary concerns reported by Shrestha et al. (2022) is the limited distance range of the cars. Limited range is a major challenge for individuals who travel longer distances. Another issue is the unavailability of charging stations in some parts of the country. In Europe, Szumska (2023) reported that the lack of adequate charging stations along major highways accounts for the low uptake of electric vehicles as an alternative to fossil fuels. Additional factors include high cost of electricity, high purchase price and mistrust of the new technologies (Giansoldati et al., 2020). Based on this, the study's findings on the penetration of electric vehicles reflect the reality in most parts of the world.

The study reported that many households worldwide know about automation energy production and storage optimisation using electric vehicles. The study's finding reflects previous reports that report increased awareness of electric vehicles and their potential to be used in energy storage for domestic use. The determination reflects the outcomes of a previous study by McElgunn (2018) that reported that the heightened concerns about the environmental implications of alternative energy sources drive awareness about EVs and associated innovations. However, the respondents understanding of the automation and optimisation aspects remains moderate. The automation and optimisation aspects are complex and not comprehensible to most individuals. In addition, the novelty of using electric vehicles to store renewable energy in domestic settings further accounts for the moderate understanding of the population. Most people recognise electric vehicles in the context of transportation, but they do not address households' energy problems.

Most participants considered the automation and optimisation of energy storage using electric vehicles innovative and promising. The participants' perspective reflects the potential of the electric vehicles to be applied in overcoming the energy-related d challenges households face. In a study, Hossain et al. (2022) report that one of the innovative aspects of EVs is their integration into the domestic power supply. A possible approach is charging the EV using the home solar system during the day and using the car to power the house at night. Hussain et al. (2022) further clarify that the EV offers the flexibility of innovations that can be exploited to advance efficiency in producing and storing renewable energy domestically. The thoughts of the participants reflect the findings of previous research. Concurrently, some participants reported interest in the proposed system but had concerns. Another group of participants expressed uncertainties and the need for more information. Founded on this finding, the study asserts that automation and optimisation of renewable energy production and storage using electric vehicles is feasible but requires enhanced efforts to ensure adequate understanding in the population.

Integrating electric vehicles into domestic renewable energy systems confers homeowners and the environment benefits. The household benefit regarding the cost savings associated with installing the system can be considered. According to the survey, most households pay high electricity, with some paying an excess of $3000 annually. The high energy cost is mainly based on the overreliance on the grid for power supply. Guan et al. (2023) reported a general increase in the cost of electricity for domestic use worldwide. Despite the high cost of initial installation, the system will improve reliability and cost of energy for households in the long run. The environmental benefits cited by up to 61% of the population have been extensively reported in previous studies. Multiple studies report that the shift to EVs will cause a net reduction in CO_2 emissions, the main greenhouse gas associated with accelerated climate change in recent times (Ou et al., 2021). Focusing on battery electric vehicles, Sun et al. (2023) contend that adopting EVs, especially in producing and storing renewable energy, will contribute to a net reduction in emission levels. In this context, the study reveals that integrating an EV into the domestic renewable energy system has positive economic and environmental implications.

The study also identified some challenges that may impede the automation and optimisation of the use of the EV in producing and storing renewable energy in domestic settings. The high initial cost of installing domestic renewable energy systems and acquiring an EV emerged as the most cited (51.8%) challenge by participants in the study. The findings reflect previous studies that have determined that the high cost of installing solar power is the primary hindrance in most households (Qureshi et al., 2017). The cost of acquiring EVs is also high in most countries, as Alanazi (2023) reported. The initial cost of investment remains a leading challenge for most households. Additional challenges that may impact the adoption of the system include concerns about the environmental impacts of batteries, the unavailability of EVs in some countries, inadequate awareness of the potential benefits and the lack of essential infrastructure. The challenges make the integration of EVs into domestic renewable energy systems less appealing to most households. Despite the cited challenges, most participants wanted to implement such a system in their homes. The positive perspective can be attributed to the expected positive impacts on the cost of energy and the environment.

7 Recommendations

Based on the findings from the study, the automation and integration of the use of the EV in the production and storage of renewable energy for domestic settings is feasible. In addition, adopting the system will positively impact energy costs and contribute to the decrease in greenhouse gas emissions implicated in the accelerated climate change in recent decades. Based on the findings, specific actions are necessary to enhance the adoption of the system as an option for the grid energy supply in most homes.

The first recommendation is the need for favourable policies to address the initial investment costs that impact the capacity of most homes to shift to renewable energy sources. The participants in the study reported a high initial cost as an important barrier to integrating the EV into the domestic renewable energy system. The recommendation requires a policy intervention by the government focusing on different areas, such as taxes and incentives, to make solar systems and EVs more affordable and accessible to households in various regions globally.

The confirmed feasibility of the automation and optimisation of EV integration into the domestic energy system necessitates the creation of awareness about the impacts on power costs and environmental impacts. In creating awareness, the focus should be on the automation and optimization aspects, as most households already know solar panels as an alternative to the main grid energy supply and the need for EVs. An improved understanding of the implications of the system on power costs and the environment will influence the decision to install automated and optimized systems that integrate EVs into domestic renewable energy systems.

In promoting the adoption of the automated and optimized system for the integration of EVs into the home grid, specific interventions for the management of the disposal of the EV batteries at the end of their life cycles must be established and reviewed periodically. The consideration of this aspect is in line with the need for environmental sustainability. The used batteries from EVs are increasingly becoming a concern with the increased adoption. Developing innovative ways to manage waste will be consequential in advancing the goal of reduced power costs and reliability for households worldwide.

8 Conclusion

The study explored the feasibility and impacts of automating and optimizing domestic renewable energy production from photovoltaics, incorporating electrically powered vehicles as secondary cycling storage. Motivated by the rising cost of electricity and its implications for the cost of living, the EV incorporation into domestic power systems is seen as a significant step in promoting them as an alternative to fossil fuels. This achievement would be instrumental in reducing environmental impacts and creating an additional income stream for homes with surplus energy.

Primarily, adopting this system is a crucial measure in slowing down and addressing global climate change issues. The study utilized a survey approach to assess the feasibility and impacts of an automated and optimized system using EVs for domestic power storage and supply. According to the study's findings, the system is feasible and has positive economic and environmental implications. Economically, households would benefit from reduced power costs, increased reliability, and the potential for extra income from surplus energy.

In light of the thesis results, future studies should concentrate on developing efficient systems to facilitate automation and optimization as well as exploring ways to reduce integration costs.

References

Alan, A. T. (2016). *People's interaction with future autonomous energy systems in their everyday lives at home* (Doctoral dissertation, University of Southampton).

Alanazi, F. (2023). Electric Vehicles: Benefits, Challenges, and Potential Solutions for Widespread Adaptation. *Applied Sciences*, *13*(10), 6016.

Ali, E. S., Hasan, M. K., Hassan, R., Saeed, R. A., Hassan, M. B., Islam, S., ... & Bevinakoppa, S. (2021). Machine learning technologies for secure vehicular communication in the internet of vehicles: recent advances and applications. *Security and Communication Networks*, *2021*, 1-23.

Alonso, M., Amaris, H., Germain, J. G., & Galan, J. M. (2014). Optimal charging scheduling of electric vehicles in smart grids by heuristic algorithms. *Energies*, *7*(4), 2449-2475.

Al-Shamani, A. N., Othman, M. Y. H., Mat, S., Ruslan, M. H., Abed, A. M., & Sopian, K. (2015). Design and sizing of stand-alone solar power systems in a house in Iraq. *Design & Sizing of Stand-alone Solar Power Systems A house Iraq Ali*, 145-150.

Alsharif, A., Tan, C. W., Ayop, R., Dobi, A., & Lau, K. Y. (2021). A comprehensive review of energy management strategy in Vehicle-to-Grid technology integrated with renewable energy sources. *Sustainable Energy Technologies and Assessments*, *47*, 101439.

Antonopoulos, I., Robu, V., Couraud, B., Kirli, D., Norbu, S., Kiprakis, A., ... & Wattam, S. (2020). A systematic review of artificial intelligence and machine learning approach to energy demand-side response. *Renewable and Sustainable Energy Reviews*, *130*, 109899.

ArunKumar, K. E., Kalaga, D. V., Kumar, C. M. S., Kawaji, M., & Brenza, T. M. (2022). Comparative analysis of Gated Recurrent Units (GRU), Long Short-Term Memory (LSTM) cells, autoregressive integrated moving average (ARIMA), and seasonal autoregressive integrated moving average (SARIMA) for forecasting COVID-19 trends. *Alexandria Engineering Journal*, *61*(10), 7585-7603.

Aslam, S., Khalid, A., & Javaid, N. (2020). Towards efficient energy management in smart grids considering microgrids with day-ahead energy forecasting. *Electric Power Systems Research*, *182*, 106232.

Bayindir, R., Hossain, E., & Vadi, S. (2016, March). The path of the smart grid- the new and improved power grid. In *2016 International Smart Grid Workshop and Certificate Program (ISGWCP)* (pp. 1-8). IEEE.

Benchrifa, M., & Mabrouki, J. (2022). Simulation, sizing, economic evaluation and environmental impact assessment of a photovoltaic power plant for the electrification of an establishment. *Advances in Building Energy Research*, *16*(6), 736-753.

Beth Burmahl (2022,March) Estimating the economic impact of electric vehicle charging stations , https://www.anl.gov/article/estimating-the-economic-impact-of-electric-vehicle-charging-stations.

Berahab, R. (2022). The Energy Crisis of 2021 and its Implications for Africa. Policy, (1967).

Bernai, R. R. (2013). Renewable Energy Sources and Climate Change Mitigation, Special Report of the Intergovernmental Panel on Climate Change (IPCC).

Bin Mofidul, R., Alam, M. M., Rahman, M. H., & Jang, Y. M. (2022). Real-time energy data acquisition, anomaly detection, and monitoring system: Implement a secured, robust, and integrated global IIoT infrastructure with edge and cloud AI. *Sensors*, *22*(22), 8980.

Chikate, B. V., Sadawarte, Y., & Sewagram, B. D. C. O. E. (2015). The factors affecting the performance of solar cells. *International journal of computer applications*, *1*(1), 0975-8887.

Destek, M. A., & Aslan, A. (2017). Renewable and non-renewable energy consumption and economic growth in emerging economies: Evidence from bootstrap panel causality. *Renewable Energy*, *111*, 757-763.

do Prado, J. C., Qiao, W., Qu, L., & Agüero, J. R. (2019). The next-generation retail electricity market in distributed energy resources: Vision and integrating framework. *Energies*, *12*(3), 491.

Dulău, L. I., & Bică, D. (2020). Effects of electric vehicles on power networks. Procedia Manufacturing, 46, 370-377.

Elangovan, U. (2021). Industry 5.0: The future of the industrial economy. CRC Press.

Elkazaz, M., Sumner, M., Davies, R., Pholboon, S., & Thomas, D. (2019, September). Optimisation-based real-time home energy management in the presence of renewable energy and battery energy storage. In *2019 International Conference on Smart Energy Systems and Technologies (SEST)* (pp. 1-6). IEEE.

Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, prospects and their enabling technology. *Renewable and sustainable energy reviews*, *39*, 748-764.

Gandoman, F. H., Ahmadi, A., Sharaf, A. M., Siano, P., Pou, J., Hredzak, B., & Agelidis, V. G. (2018). Review of FACTS technologies and applications for power quality in smart grids with renewable energy systems. *Renewable and sustainable energy reviews*, *82*, 502-514.

Gastinger, J., Nicolas, S., Stepić, D., Schmidt, M., & Schülke, A. (2021, July). A study on ensemble learning for time series forecasting and the need for meta-learning. In *2021 International Joint Conference on Neural Networks (IJCNN)* (pp. 1-8). IEEE.

Giansoldati, M., Monte, A., & Scorrano, M. (2020). Barriers to the adoption of electric cars: Evidence from an Italian survey. Energy Policy, 146, 111812.

Gu, Y., Wang, J., Liang, Z., Wu, Y., Cecati, C., & Zhang, Z. (2020). Single-transmitter multiple-pickup wireless power transfer: Advantages, challenges, and corresponding technical solutions. *IEEE Industrial Electronics Magazine*, *14*(4), 123-135.

Guan, Y., Yan, J., Shan, Y., Zhou, Y., Hang, Y., Li, R., ... & Hubacek, K. (2023). The burden of the global energy price crisis on households. Nature Energy, 1-13.

Hasan, M. K., Mahmud, M., Habib, A. A., Motakabber, S. M. A., & Islam, S. (2021). Review of electric vehicle energy storage and management system: Standards, issues, and challenges. Journal of Energy Storage, 41, 102940.

Heinberg, R., & Fridley, D. (2016). *Our renewable future: Laying the path for one hundred per cent clean energy*. Island Press

Hossain, M. S., Kumar, L., El Haj Assad, M., & Alayi, R. (2022). Advancements and prospects of electric vehicle technologies: a comprehensive review. Complexity, 2022, 1-21.

Jacob, A. S., Banerjee, R., & Ghosh, P. C. (2018). Sizing of hybrid energy storage system for a PV-based microgrid through design space approach. *Applied Energy*, *212*, 640-653.

J. Hiratsuka, G. Perlaviciute, L. Steg. (2018). Testing VBN theory in Japan: Relationships between values, beliefs, norms, and acceptability and expected effects of a car pricing policy,Transportation Research Part F: Traffic Psychology and Behaviour, 53, 74-83

Keshan, H., Thornburg, J., & Ustun, T. S. (2016). Comparison of lead-acid and lithium-ion batteries for stationary storage in off-grid energy systems.

Khaldi, K. (2017). Quantitative, qualitative or mixed research: Which research paradigm to use? *Journal of Educational and Social Research*, *7*(2), 15.

Lazard. (2020). Lazard's levelized cost of energy analysis—Version 14.0. Lazard Ltd.

Liu, X., Liu, C., Han, W., & Pong, P. W. (2018). Design and implement a multi-purpose TMR sensor matrix for wireless electric vehicle charging. *IEEE Sensors Journal*, *19*(5), 1683-1692

Mazhar, T., Asif, R. N., Malik, M. A., Nadeem, M. A., Haq, I., Iqbal, M., ... & Ashraf, S. (2023). Electric Vehicle Charging System in the Smart Grid Using Different Machine Learning Methods. *Sustainability*, *15*(3), 2603.

McKinsey (2021). Mainstream EVs will transform the automotive industry and help decarbonise the planet. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/why-the-automotive-future-is-electric#/

McElgunn, J. (2018). Consumer Awareness of Electric Vehicles and Global Purchasing Patterns.

McLoughlin, F., Duffy, A., & Conlon, M. (2013). Evaluation of time series techniques to characterise domestic electricity demand. *Energy*, *50*, 120-130.

Melhem, F. Y., Grunder, O., Hammoudan, Z., & Moubayed, N. (2017). Optimisation and energy management in smart home considering photovoltaic, wind, and battery storage systems integrating electric vehicles. *Canadian Journal of Electrical and Computer Engineering*, *40*(2), 128-138.

Mesarić, P., Đukec, D., & Krajcar, S. (2017). We are exploring the potential of energy consumers in smart grids using focus group methodology: Sustainability, *9*(8), 1463.

Misra, S., Roy, C., & Mukherjee, A. (2021). *Introduction to industrial Internet of Things and Industry 4.0*. CRC Press.

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 integration to the grid and renewable energy sources. *Renewable and sustainable energy reviews*, *34*, 501-516.

Nuhin, M. I. I., Shariar, M. A., Khan, J. M., Kongkon, T. N., & Imam, M. H. (2022). Design of an IoT-based power monitoring system model for a grid-connected solar PV. *International Journal of Advanced Technology and Engineering Exploration*, *9*(92), 923.

Ou, Y., Kittner, N., Babaee, S., Smith, S. J., Nolte, C. G., & Loughlin, D. H. (2021). Evaluating long-term emission impacts of large-scale electric vehicle deployment in the US using a human-Earth systems model. Applied Energy, 300, 117364.

Olaofe, Z. O., & Folly, K. A. (2012, July). Energy storage technologies for small-scale wind conversion systems. In 2012 IEEE Power Electronics and Machines in Wind Applications (pp. 1-5). IEEE.

Panossian, N., Muratori, M., Palmintier, B., Meintz, A., Lipman, T., & Moffat, K. (2022). Challenges and opportunities of integrating electric vehicles in electricity distribution systems. *Current sustainable/renewable energy reports*, *9*(2), 27-40.

Pivoto, D. G., de Almeida, L. F., da Rosa Righi, R., Rodrigues, J. J., Lugli, A. B., & Alberti, A. M. (2021). Cyber-physical systems architectures for industrial Internet of things applications in Industry 4.0: A literature review. Journal of manufacturing systems, 58, 176-192.

Qaisar, S. M., & Alyamani, N. (2022). A review of charging schemes and machine learning techniques for intelligent management of electric vehicles in smart grid. *Managing Smart Cities: Sustainability and Resilience Through Effective Management*, 51-71.

Qureshi, T. M., Ullah, K., & Arentsen, M. J. (2017). Factors responsible for solar PV adoption at household level: A case of Lahore, Pakistan. Renewable and Sustainable Energy Reviews, 78, 754-763.

Rahbari, O., Vafaeipour, M., Omar, N., Rosen, M. A., Hegazy, O., Timmermans, J. M., ... & Van Den Bossche, P. (2017). An optimal versatile control approach for plug-in electric vehicles to integrate renewable energy sources and smart grids. *Energy*, *134*, 1053-1067.

Rathor, S. K., & Saxena, D. (2020). Energy management system for smart grid: An overview and key issues. *International Journal of Energy Research*, *44*(6), 4067-4109.

Rawat, T., Niazi, K. R., Gupta, N., & Sharma, S. (2019). Impact assessment of electric vehicle charging/discharging strategies on the operation management of grid accessible and remote microgrids. *International Journal of Energy Research*, *43*(15), 9034-9048.

Razmjoo, A., Ghazanfari, A., Jahangiri, M., Franklin, E., Denai, M., Marzband, M., ... & Maheri, A. (2022). A Comprehensive Study on the Expansion of Electric Vehicles in Europe. Applied Sciences, 12(22), 11656.

Rogelj, J., Den Elzen, M., Höhne, N., Fransen, T., Fekete, H., Winkler, H., ... & Meinshausen, M. (2016). Paris Agreement climate proposals need a boost to keep warming well below 2 C. *Nature*, *534*(7609), 631-639.

Sawin, J. L., Sverrisson, F., Seyboth, K., Adib, R., Murdock, H. E., Lins, C., ... & Mastny, L. (2016). Renewables 2017 global status report.

Sharifzadeh, M., Sikinioti-Lock, A., & Shah, N. (2019). Machine-learning methods for integrated renewable power generation: A comparative study of artificial neural networks, support vector regression, and Gaussian Process Regression. *Renewable and Sustainable Energy Reviews*, *108*, 513-538.

Shrestha, S., Baral, B., Shah, M., Chitrakar, S., & Shrestha, B. P. (2022). Measures to resolve range anxiety in electric vehicle users. International Journal of Low-Carbon Technologies, 17, 1186-1206.

Sovacool, B. K., & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. *Applied Energy*, *142*, 435-444.

Stahl, B. C., Eden, G., & Jirotka, M. (2013). Responsible research and innovation in information and communication technology: Identifying and engaging with the ethical implications of ICTs. *Responsible innovation: Managing the responsible emergence of science and innovation in society*, 199-218.

Sun, D., Kyere, F., Sampene, A. K., Asante, D., & Kumah, N. Y. G. (2023). An investigation on the role of electric vehicles in alleviating environmental pollution: evidence from five leading economies. Environmental Science and Pollution Research, 30(7), 18244-18259

Szumska, E. M. (2023). Electric Vehicle Charging Infrastructure along Highways in the EU. Energies, 16(2), 895.

Talaat, M., Arafa, I., & Metwally, H. M. B. (2020). Advanced automation system for charging electric vehicles based on machine vision and finite element method. *IET Electric Power Applications*, *14*(13), 2616-2623.

Tan, K. M., Ramachandaramurthy, V. K., & Yong, J. Y. (2016). Integrating electric vehicles in smart grid: A review on vehicle to grid technologies and optimisation techniques. *Renewable and Sustainable Energy Reviews*, *53*, 720-732.

Tseng, H. K., Wu, J. S., & Liu, X. (2013). Affordability of electric vehicles for a sustainable transport system: An economic and environmental analysis. *Energy policy*, *61*, 441-447.

Valencia, A., Hincapie, R. A., & Gallego, R. A. (2021). Optimal location, selection, and operation of battery energy storage systems and renewable distributed generation in medium–low voltage distribution networks. *Journal of Energy Storage*, *34*, 102158.

Van der Werff, E., & Steg, L. (2016). The psychology of participation and interest in smart energy systems: Comparing the value-belief-norm theory and the value-identity-personal norm model. *Energy research & social science*, *22*, 107-114.

Venugopal, P., Shekhar, A., Visser, E., Scheele, N., Mouli, G. R. C., Bauer, P., & Silvester, S. (2018). Roadway to self-healing highways with integrated wireless electric vehicle charging and sustainable energy harvesting technologies. *Applied Energy*, *212*, 1226-1239.

Wellings, J., Greenwood, D., & Coles, S. R. (2021). Understanding the Future Impacts of Electric Vehicles—An Analysis of Multiple Factors That Influence the Market. Vehicles, 3(4), 851-871.

Wu, Y., Wang, Z., Huangfu, Y., Ravey, A., Chrenko, D., & Gao, F. (2022). An overview of the hierarchical operation of electric vehicle charging station in smart grid integration applications. *International Journal of Electrical Power & Energy Systems*, *139*, 108005.

Xu, C., Behrens, P., Gasper, P., Smith, K., Hu, M., Tukker, A., & Steubing, B. (2023). Electric vehicle batteries alone could satisfy short-term grid storage demand by early 2030. Nature Communications, 14(1), 119.

Zafar, B., & Slama, S. A. B. (2022). PV-EV integrated home energy management using vehicle-to-home (V2H) technology and household occupant behaviours. Energy Strategy Reviews, 44, 101001.

Zafar, U., Bayhan, S., & Sanfilippo, A. (2020). Home energy management system concepts, configurations, and technologies for the smart grid. *IEEE Access*, *8*, 119271-119286.

Zakeri, B., & Syri, S. (2015). Electrical energy storage systems: A comparative life cycle cost analysis. *Renewable and sustainable energy reviews*, *42*, 569-596.

Zhang, S., Yang, Q., Gao, Y., & Gao, D. (2022). Real-time fire detection method for electric vehicle charging stations based on machine vision. *World Electric Vehicle Journal*, *13*(2), 23.

Zhou, B., Pei, J., Calautit, J. K., Zhang, J., & Guo, F. (2021). Solar self-powered wireless charging pavement—a review on photovoltaic pavement and wireless charging for electric vehicles. *Sustainable Energy & Fuels*, *5*(20), 5139-5159.

Appendix 1. Survey Questionnaire

Survey :Public Perception Survey on Automation and Optimization of Renewable Domestic Energy Production and Storage using Electrical Vehicles

This survey is part of my Thesis process at Hamk University of Applied sciences.

The purpose of this research study is to explore the feasibility and viability of integrating electric vehicles into renewable energy production and storage systems in domestic settings. Additionally, the research will examine the economic, environmental, and social impacts of such automation and optimization.

I would sincerely appreciate it if you could take a few moments to participate in the survey. Your valuable input is essential to the success of this study. In addition to providing a comprehensive understanding of public perceptions regarding the automation and optimization of renewable energy using electric vehicle batteries, the study's findings may have implications for shaping policy initiatives to promote the use of renewable energy.

Incase of any questions please reach out via my university email:
francis.manyonje@student.hamk.fi

Age Category *

- ○ 18-30 Year
- ○ 31- 40 Years
- ○ 41-50 Year
- ○ Over 50

Gender

- ○ Male
- ○ Female
- ○ Other
- ○ Prefer not to say

Location *

- ◯ Africa
- ◯ Europe
- ◯ Asia
- ◯ America
- ◯ Australia

Country *

Choose ▾

What type of vehicle do you currently drive? Select one or more *

- ◯ Diesel
- ◯ Petrol
- ◯ Electric Car
- ◯ Hybrid
- ◯ I do not own a car

Have you heard about the concept of using electric vehicles (EVs) for storing and managing renewable energy at home? *

- ◯ Yes
- ◯ No

How well do you understand the idea of automating and optimizing renewable energy production and storage using EVs? *

- ◯ Very well
- ◯ Moderately well
- ◯ Slightly well
- ◯ Not at all

What is your main source of domestic energy? *

- ◯ Electricity
- ◯ Natural Gas
- ◯ Solar Panels

Approximately how much do you spend on energy annually? *

- ◯ Less than $600
- ◯ $500 to $1,000
- ◯ $1,000 to $2,000
- ◯ More than $3,000
- ◯ Prefer not to answer

What are your initial thoughts on the use of electric vehicles for storing excess renewable energy generated in households *

- ☐ Innovative and promising solution
- ☐ Interested but have some concerns
- ☐ Not sure or need more information

Do you believe this system could benefit homeowners and the environment? *

- ◯ Yes, it could benefit both homeowners and the environment.
- ◯ Maybe, I have some doubts or concerns.
- ◯ No, I don't think it would benefit either.
- ◯ I'm not sure or need more information to decide.

What potential challenges or concerns do you see with implementing this system *

- ☐ High initial costs
- ☐ Limited availability of electric vehicles
- ☐ Environmental impact of battery production
- ☐ Grid infrastructure compatibility
- ☐ Security and data privacy issues
- ☐ Lack of awareness and education
- ☐ All the above
- ☐ Other: ______

Would you consider adopting such a system in your own home for renewable energy storage and management *

- ◯ Yes
- ◯ No
- ◯ Not sure

Do you have any additional comments or suggestions regarding the concept of using electric vehicles for renewable energy automation and optimization

Your answer ______

Submit

Clear form

Appendix 2. Additional comments by the respondents

The question about "potential challenges or concerns with implementing this system" and addressing the data privacy concerns should be considered. While IoT and hyper-connectivity is great, there are many nodes in the system, and in case there is a data breach, it can lead to some major privacy breach

Great initiative considering the trajectory of implementing the use of electronic vehicles with in Australia.

In Finland, the issues related to electric cars themselves are still very challenging. The stock of electric car will not grow at the expected pace unless certain changes are made.

I intend to add solar panels to my house in 2024/2025 but will use Feed in Tarrifs so my generated electricity will go into the grid and not into storage batteries in my home….so this system will likely not be compatible with