

Challenges and Future Prospects of Electric Vehicles Using Hybrid Energy in Bangladesh - A Case Study

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Abstract—The main objective of this paper is to review the current challenges and prospects of Electric Vehicles based hybrid energy in Bangladesh. Electric cars (EVs) are a viable way to lessen transportation's negative environmental effects and wean us from fossil fuels. EV adoption has a lot of promise in Bangladesh, where environmental sustainability and energy security are major concerns. However, there are a few obstacles to the general adoption of EVs, including limited infrastructure, high upfront prices, and range anxiety. The difficulties and potential benefits of EVs using hybrid energy in Bangladesh are examined in this case study. It has been reviewed the infrastructure's preparedness, present level of EV adoption, and main obstacles for implementation. In addition, it has been suggested tactics to address these issues, such as public awareness campaigns, infrastructure development, and regulatory changes. It is considered to look at how hybrid energy systems, which combine traditional power grids and renewable energy sources, can power EVs and improve energy sustainability. Bangladesh can achieve sustainable transportation goals, decrease greenhouse gas emissions, and expedite the shift to electric mobility by utilizing hybrid energy solutions and tackling systemic issues. Policymakers, industry stakeholders, and scholars can use this case study to gain important insights into how Bangladesh's energy transition and EV adoption are changing.

Keywords—Electric Vehicles, Hybrid Energy, Bangladesh, Challenges, Prospects

I. INTRODUCTION

EVs have the potential to lessen the negative effects of transportation on air quality and climate change [1], and nations like Bangladesh are investigating this possibility more and more as concerns about energy security and environmental degradation grow. But Bangladesh is facing several obstacles in its move to electric vehicles (EVs), such as inadequate infrastructure, unfavorable laws, and impediments to technology [2]. Furthermore, there are potential challenges for fueling EVs responsibly due to the country's energy landscape, which is defined by a combination of conventional and renewable energy sources. To alleviate environmental issues, lessen reliance on fossil fuels, and advance environmentally friendly transportation globally, electric cars, or EVs, have gained significant traction. The main objective of this case study is to examine the difficulties and potential benefits of hybrid energy consumption in Bangladesh for electric vehicles. With regard to EV adoption, infrastructural preparedness, and policy

frameworks nationwide, our goal is to present a thorough picture. In order to determine ways to expedite the adoption of electric mobility while maintaining energy sustainability and environmental stewardship, we look at the current obstacles to EV deployment and evaluate the possibilities of hybrid energy solutions.

This study intends to provide insights into the opportunities and problems involved with integrating EVs into Bangladesh's transportation system by a thorough examination of case studies, data analysis, and policy assessment. Through an understanding of the distinct socio-economic, technological, and regulatory factors influencing Bangladesh's electric vehicle (EV) landscape, stakeholders can devise focused interventions aimed at surmounting obstacles and unleashing the complete possibilities of electric mobility. By utilizing the synergies between electric vehicles and hybrid energy solutions, this case study ultimately aims to support informed decision-making and policy formation to accelerate Bangladesh's transition towards sustainable mobility. Globally, interest in electric vehicles (EVs) has grown as a critical tool in the fight against climate change, reduction of air pollution, and attainment of energy independence [3]. Adoption of EVs has tremendous promise in Bangladesh, a densely populated country struggling with issues such as urban congestion, declining air quality, and energy insecurity. Nonetheless, Bangladesh's move to electric vehicles has special opportunities and challenges that should be carefully considered.

In Bangladesh, the adoption of electric vehicles (EVs) presents a chance to address urgent socio-economic problems in addition to meeting environmental requirements [4]. The need for transportation is growing rapidly due to urbanization and economic expansion, which is raising pollution levels, clogging roads, and using more energy. Compared to conventional cars, EVs provide a sustainable option that lowers emissions, lessens reliance on imported fossil fuels, and promotes economic resilience. There are several obstacles standing in the way of Bangladesh's mainstream EV adoption, even with the potential advantages. Significant obstacles to the widespread adoption of EVs are caused by inadequate road networks, a lack of charging stations, and restrictions in grid capacity. In addition, regulatory obstacles, high upfront costs, and little customer awareness prevent market penetration and investment in electric mobility [5]. Given these circumstances, hybrid energy makes a strong

case for being used to alleviate Bangladesh's EV adoption problems. Hybrid energy systems provide a dependable and sustainable power source for EV charging by fusing renewable energy sources like solar, wind, and hydropower with traditional grid infrastructure. This combination of renewable energy and electric mobility is in line with Bangladesh's commitment to sustainable development and climate action.

In order to better understand the complexities of EV integration with hybrid energy systems in Bangladesh, we have conducted this case study. We want to identify solutions to overcome obstacles and unlock the full potential of EV adoption by studying the existing state of electric mobility, evaluating policy frameworks, and assessing infrastructure deficiencies. To get further insights and lessons that apply to the Bangladeshi context, we will also look at successful case studies and best practices from other nations. We can pave the way for sustainable transportation in Bangladesh by encouraging cooperation between public and private sector entities as well as civil society organizations [6]. We can ensure energy security, environmental sustainability, and socioeconomic growth while expediting the shift to electric mobility through targeted interventions, creative funding methods, and public-private partnerships.

The integration of various renewable energy sources, including solar, wind, hydro, and biomass, with conventional energy sources or energy storage devices is known as hybrid energy systems. By utilizing the complementing qualities of several energy sources, these systems are made to maximize energy production, boost system resilience, and increase reliability. Sustainable mobility refers to transportation policies and procedures that reduce their negative effects on the environment, encourage energy conservation, and give accessibility and social justice first priority. It entails implementing laws and infrastructure that enable the use of cleaner, more efficient forms of transportation, such as electric cars (EVs), public transportation, cycling, and walking.

The main contribution of this paper is that the case study educates stakeholders about the most recent developments in EV and hybrid energy system technology through a thorough analysis of technological potential and obstacles [7]. It offers perceptions into cutting-edge approaches to boosting battery technology, upgrading the infrastructure for charging, and maximizing energy efficiency in hybrid systems. The transportation and energy sectors in Bangladesh can use this information to determine investment choices and technology adoption plans.

II. HYBRID ENERGY SOURCES

Systems that combine two or more distinct energy sources to produce electricity or power are commonly referred to as hybrid energy sources. By utilizing the advantages of each energy source, these systems increase overall sustainability, dependability, and efficiency [8]. These are only a few instances of hybrid energy sources that highlight the adaptability and promise of fusing several energy technologies to satisfy a range of energy requirements and further sustainability and resilience objectives. Several typical hybrid energy sources are as follows:

- **Wind and Solar:** One common hybrid energy solution combines wind turbines with photovoltaic (PV) solar panels. Wind turbines provide power when there is enough wind to warrant it, whereas solar panels provide electricity during the day [8]. Hybrid solar-wind systems maximize energy generation and grid stability by combining these two renewable energy sources to provide more electricity consistently day and night.
- **Solar and Diesel Generators:** Hybrid solar-diesel systems are utilized to produce dependable electricity in rural or off-grid areas with restricted access to grid power. Diesel fuel usage decreases during the day when solar panels produce power [9]. In times of poor solar radiation or heavy electricity demand, diesel generators act as backup power sources, guaranteeing a steady supply while reducing fuel expenses and emissions.
- **Hydro and Solar:** Hybrid hydro-solar systems can be produced by combining solar PV panels with hydroelectric power facilities. Solar panels complement hydropower generation during periods of abundant sunlight, saving water and improving overall system efficiency [10]. Hybrid hydro-solar systems provide a reliable and sustainable energy source in areas where water availability and sun irradiance vary seasonally.
- **Solar and Biomass:** In hybrid energy systems, biomass energy which comes from organic materials like wood chips, municipal garbage, and agricultural residues can supplement solar electricity. Baseload power can be produced by methane digesters or biomass-fired generators, and throughout the day, solar panels can offer extra electricity [11]. Hybrid biomass-solar systems provide dependable and sustainable energy solutions for rural communities and enterprises by harnessing locally accessible biomass resources.
- **Solar and Geothermal:** In hybrid geothermal-solar systems, solar power is blended with geothermal energy, which is drawn from the heat of the earth. Geothermal facilities can use solar panels to balance their electricity use throughout the day, which lowers energy prices overall and has a positive environmental impact. Improved energy security and resilience are provided by hybrid geothermal-solar systems, especially in areas with plenty of sunshine and geothermal resources [12].
- **Grid-Tied and Battery Storage:** Grid-tied solar or wind electricity can also be combined with battery storage systems in hybrid energy systems. Batteries can be used to store extra electricity produced from renewable sources during times of low demand, which can then be used during times of peak demand or power disruptions [13]. Battery-powered hybrid systems that are connected to the grid improve energy independence, lessen dependency on fossil fuels, and promote grid resilience.

III. HYBRID ENERGY BASED EVS IN BANGLADESH

Electric vehicles (EVs) based on hybrid energy have a lot of potential for Bangladesh because they provide an effective and sustainable way to address the nation's energy and transportation needs. Hybrid energy systems can improve the efficiency, dependability, and performance of electric vehicles (EVs) while advancing environmental sustainability and energy security by integrating a variety of energy

sources, including conventional and renewable fuels [14]. Bangladesh has made great progress toward electrifying rural regions by installing solar home systems (SHS). These systems use solar panels that are mounted on the roofs of homes to provide clean, renewable energy for charging mobile phones, small appliances, and lights. However, many SHS systems include backup diesel generators to mitigate the intermittent nature of solar power and guarantee a steady supply of electricity. Communities have been supplied with energy using hybrid mini-grids that combine solar, wind, and battery storage technologies in rural and off-grid places where grid extension is not practical.

Bangladesh has a lot of potential for hybrid energy-based EVs since they provide an effective and sustainable way to address the country's energy and transportation needs. Bangladesh can hasten the shift to electric transportation and create a cleaner, greener, and more affluent future for all by utilizing renewable energy resources, improving energy efficiency, putting supportive legislation into place, increasing public awareness, and encouraging industrial development. Key factors and future prospects for hybrid energy-based electric vehicles (EVs) in Bangladesh are as follows:

- **Integration of Renewable Energy:** Bangladesh possesses a wealth of renewable energy resources that can be used with hybrid energy systems to power electric vehicles (EVs), such as biomass, solar, and wind energy [15]. Bangladesh may lower carbon emissions, improve energy security, and advance environmental sustainability by utilizing renewable energy sources, such as solar-powered charging stations and wind-powered auto fleets.
- **Enhanced Energy Efficiency:** By optimizing energy use through regenerative braking, smart charging, and energy management systems, hybrid energy-based EVs offer enhanced energy efficiency over traditional vehicles. Hybrid electric vehicles (EVs) can minimize their dependency on fossil fuels, maximize the use of renewable energy sources, and lessen their environmental effect.
- **Grid Stability and Load control:** In Bangladesh, integrating EVs with the electrical grid may present difficulties with regard to peak demand, load control, and grid stability. Hybrid energy systems, such as battery-storage equipped grid-tied EV charging stations, can lessen these difficulties by offering demand response, peak shaving, and grid support services [16]. Hybrid electric vehicles (EVs) enhance the stability and resilience of the grid by maximizing energy flows and adjusting supply and demand.
- **Policy Support and Incentives:** To hasten Bangladesh's adoption of EVs powered by hybrid energy, robust policy support and incentives are necessary. An environment that is supportive of sustainable energy and transportation solutions can be created by government initiatives including tax breaks, financial aid for the purchase of electric vehicles, and rules requiring the integration of renewable energy sources [17].
- **Public Education and understanding:** Promoting consumer acceptance and adoption of hybrid energy-based electric vehicles (EVs) requires raising public understanding of the advantages of these vehicles [18].

The environmental, financial, and social benefits of hybrid electric vehicles (EVs) can be better understood by the public through outreach efforts, educational programs, and demonstration projects. This will dispel myths and promote adoption among consumers, companies, and legislators.

- **Industry Development and Innovation:** The introduction of EVs powered by hybrid energy offers Bangladeshi industries the chance to grow, innovate, and create jobs. The shift to electric mobility presents opportunities for job creation, skill development, and industrial expansion, from the production and assembly of EV components to the installation and upkeep of charging infrastructure. Bangladesh may establish itself as a center for environmentally friendly transportation by cultivating an ecosystem that is conducive to EV manufacturing, research, and innovation [19].

IV. HYBRID ENERGY GENERATION ALGORITHMS

The efficient integration and administration of hybrid energy production systems depends heavily on algorithms. By carefully balancing the use of various renewable energy sources, algorithms make it possible to maximize energy production and consumption [20]. In order to decide the best distribution of energy sources, storage technologies, and grid interactions, they take into account variables including resource availability, energy demand, cost, and environmental considerations. The maximum possible integration of renewable energy sources into the hybrid system is made possible by algorithms. A comparative table of various algorithms used in hybrid energy generation system has been shown in table 2. For renewable energy sources, they use methods like maximum power point tracking (MPPT) [21], which allow them to function at their best efficiency and harvest the most energy possible. Algorithms aid in maximizing the use of clean and sustainable energy sources by dynamically adjusting the energy generation based on the availability of renewable resources. Within the hybrid energy system, algorithms allow for efficient load balancing and energy management [22]. To ensure dependable and effective operation, they optimize the allocation and distribution of energy across various sources, storage systems, and loads. In order to decide wisely regarding energy routing, storage control, and load scheduling, algorithms take into account real-time data such as energy demand, resource availability, and battery state-of-charge [23].

In hybrid energy systems, machine learning algorithms are crucial for preserving the reliability of the grid and the quality of the power [24]. They combine reactive power management, frequency control, and voltage regulation control procedures to make sure the system functions within the desired parameters [25]. Algorithms offer the versatility and flexibility required to instantly react to these changing settings. They can swiftly modify the energy distribution, storage management, and grid interactions. Optimizing the economic feasibility of hybrid energy systems is made possible by algorithms [26]. by taking into account elements such as the cost of fuel, the price of electricity, operating and maintenance expenditures, and prospective revenue sources. Based on anticipated energy demand, resource availability,

and system limits, algorithms aid in the design and sizing of energy sources, storage systems, and control mechanisms.

The Hierarchical Control Strategy (HCS) is a frequently employed method to produce hybrid energy in microgrid [27]. A hybrid energy system's use of numerous energy sources can be optimized with the help of the HCS algorithm. It consists of a hierarchical structure with various control levels, each in charge of managing a certain function of the system [28]. The real-time management of specific energy sources, such as solar cells, wind turbines, or traditional generators, is the primary focus of the primary control level. The local functioning of each source, including maximum power point tracking, voltage and frequency regulation, and load balancing, is managed at the primary control level. Within the hybrid energy system, the secondary control level supervises the workings of various energy sources and storage technologies. It seeks to maximize overall performance and guarantee resource utilization. Energy demand, energy supply from various sources, and energy storage levels are all considered at the secondary control level. The hybrid energy system's long-term planning and optimization are the primary concerns of the tertiary control level. To make strategic decisions, it considers elements such as the state of the energy market, forecasts for the future energy demand, and environmental factors. The sizing of energy storage systems, the long-term scheduling of energy generation, and the best capacity allocation of various energy sources are all determined at the tertiary control level to maximize economic and environmental benefits. Within a hybrid energy system, the HCS algorithm facilitates the coordination and optimization of various energy sources, storage systems, and control mechanisms [29]. It handles the erratic and intermittent nature of renewable energy sources while simultaneously taking the grid's requirements for stability and dependability into account. To maintain optimal energy generation, storage, and distribution, the algorithm continuously checks and modifies the system's operation depending on real-time data and system conditions. It's crucial to remember that the HCS algorithm's implementation and customization may differ based on the properties of the hybrid energy system, such as the combination of energy sources, energy storage options, and grid needs.

It's significant to note that the hybrid energy generation system's unique qualities and requirements influence the algorithms chosen and how they are put into practice. Depending on the individual system design and goals, the algorithm steps for producing hybrid energy may change. The processes depicted in fig.1 should be understood as a basic overview. The exact algorithmic implementation will rely on the system requirements, control goals, and available resources. To attain optimum performance and operational efficiency, the algorithm should be customized to the unique traits and limitations of the hybrid energy generation system. Based on variables like the mixture of energy sources, system size, grid circumstances, and operational goals, integration algorithms are frequently developed and fine-tuned. To improve the efficiency and integration of hybrid energy generation systems, numerous algorithms are frequently utilized.

- Genetic Algorithms (GA): In hybrid energy systems, genetic algorithms are employed as optimization

techniques. The scheduling and operation of diverse energy sources and storage systems can be optimized using GA depending on a variety of restrictions and goals, such as lowering costs, maximizing the use of renewable energy sources, or cutting carbon emissions [30].

- Maximum Power Point Tracking (MPPT): To obtain the most power possible from renewable energy sources like solar and wind, MPPT algorithms are frequently utilized [31]. To match the best power production, they continuously monitor and modify the operating parameters of the renewable energy systems, taking into consideration factors like wind speed and sun irradiation. MPPT algorithms make ensuring that renewable energy sources function as efficiently as possible and contribute to total energy production.
- Particle Swarm Optimization (PSO): PSO algorithms can be used in hybrid energy systems to regulate and operate different energy sources, storage systems, and grid interfaces more effectively [32]. To identify the best solution, PSO algorithms iteratively update the positions and velocities of particles in a search space.
- Model Predictive Control (MPC): MPC can be utilized in hybrid energy systems to improve energy dispatch and manage the performance of various energy sources and storage systems. MPC algorithms can make real-time control decisions to save costs, maximize the use of renewable energy sources, and preserve system stability by considering projections of future energy supply, demand, and grid conditions [33].
- Reinforcement Learning (RL): Based on reward signals, RL algorithms can be used in hybrid energy systems to optimize the operation and control of energy sources and storage systems [34]. Through trial and error, RL algorithms eventually identify the control actions that result in desired results, such as maximizing the integration of renewable energy, lowering prices, or cutting emissions.
- Fuzzy Logic Control (FLC): To create optimized control decisions in hybrid energy systems based on linguistic variables and regulations, FLC algorithms can be used [35]. The management of the unpredictability and intermittency of renewable energy sources as well as the enhancement of their integration with traditional sources can be accomplished using FLC algorithms because of their capacity to handle uncertainties and inaccurate information.
- Economic Dispatch Algorithms (EDA): Economic dispatch algorithms seek to maximize the distribution of energy output across various energy sources while minimizing the cost of energy production overall [36]. The ideal power output from each energy source in a hybrid system is determined by these algorithms considering variables including fuel costs, energy prices, generating constraints, and transmission limitations.

V. CHALLENGES OF EVs USING HYBRID ENERGY

In order to achieve widespread adoption and a smooth integration into transportation networks, electric vehicles (EVs) that use hybrid energy sources must overcome a number of obstacles. Coordination between government organizations, business partners, academic institutions, and

advocacy organizations is needed to address these issues [34]. In order to fully utilize electric vehicles with hybrid energy systems and advance sustainable mobility solutions, cooperative efforts to invest in infrastructure, encourage technological development, and raise consumer awareness are crucial. These are a few of the major obstacles:

- **Infrastructure Development:** The requirement for infrastructure development is one of the main obstacles facing EVs that use hybrid energy. This involves setting up stations allowing hybrid electric vehicles (HEVs) to be refueled or have their batteries changed, as well as charging stations for plug-in hybrid electric vehicles (PHEVs) [35]. Building a strong network of infrastructure for charging EVs is crucial to encouraging their adoption and reducing range anxiety in drivers.
- **Grid Integration:** There are technological difficulties in integrating EV charging infrastructure with the electrical grid, especially when it comes to load balancing, peak demand management, and system stability. Significant electrical power is needed for EV charging stations, and the simultaneous use of these stations might put pressure on local distribution networks [36]. Demand response initiatives, energy management platforms, and smart grid technologies are required to maximize grid integration and reduce effects on power distribution.
- **Battery Technology:** For EVs using hybrid energy, the cost and performance of batteries continue to be major obstacles. Although the most popular energy storage technology for electric vehicles (EVs) is lithium-ion batteries, improvements in battery chemistry, energy density, and endurance are required to increase driving range, shorten charging times, and cut prices. Furthermore, there are environmental issues with spent battery recycling and disposal that must be resolved in a sustainable manner [37].
- **Cost & Affordability:** For many consumers, the initial cost of electric vehicles (EVs) and hybrid energy systems continues to be a barrier to adoption. Even while the cost of EVs has been going down, they are still typically more expensive than cars with internal combustion engines. Comparatively speaking, hybrid energy systems which integrate several energy sources may require a larger initial investment than conventional energy systems [38].
- **Range and Performance:** One major worry for EV drivers is range anxiety, or the dread of running out of battery power while driving. Although hybrid energy systems can reduce range restrictions by using other energy sources (such as gasoline or hydrogen), improving battery efficiency and the infrastructure for charging them is crucial to boosting the range and dependability of electric vehicles. To improve electric vehicle (EV) performance and allay consumer worries regarding range restrictions, advancements in battery technology, energy management systems, and vehicle design are required [39].
- **Consumer Acceptance and Awareness:** A lot of people still don't know much about electric vehicles (EVs) and may have preconceived notions about how reliable, efficient, and affordable they are. To increase adoption rates, it is essential to inform consumers about the advantages of electric vehicles (EVs) and hybrid energy systems, address issues with range anxiety and charging

infrastructure, and highlight the financial and environmental benefits of electric mobility. Campaigns for public awareness, outreach initiatives, and incentives for buying electric vehicles can hasten the adoption of EVs by consumers.

VI. PROSPECTS OF EVs USING HYBRID ENERGY

There are several possible advantages and opportunities for Bangladesh from the use of hybrid energy in electric cars (EVs). Bangladesh aims to achieve sustainable development, lower environmental pollution, improve energy security, and stimulate economic growth. The prospects for electric vehicles operating on hybrid energy are in line with these objectives. Bangladesh can tackle urgent energy and environmental issues and generate new prospects for growth and creativity by adopting electric vehicles and renewable energy technology.

- **Energy Security:** Bangladesh's increasing energy needs, especially for transportation, present obstacles. The nation may lessen its reliance on imported fossil fuels, improve energy security, and diversify its energy mix by encouraging the deployment of electric vehicles (EVs) powered by hybrid energy [40]. By combining traditional grid electricity with renewable energy sources like solar and wind, hybrid energy systems provide a sustainable way to meet transportation needs and lessen dependency on imported gas and oil.
- **Environmental Sustainability:** In Bangladesh, EVs running on hybrid energy have the potential to drastically cut down on air pollution and greenhouse gas emissions. By substituting traditional internal combustion engine cars with electric and hybrid models, the nation can lessen the negative effects of transportation on public health and air quality. Renewable energy sources used in hybrid energy systems can lower carbon emissions and improve environmental sustainability.
- **Cost Savings:** In Bangladesh, businesses and customers alike can see cost savings by utilizing electric vehicles that run on hybrid energy. EVs may cost more up front than traditional cars, but over time they may save money due to decreased running costs, such as fuel and maintenance expenditures [41]. Hybrid energy systems can also lower dependency on the unstable fossil fuel markets and help stabilize energy prices, which benefits both energy users and car owners financially.
- **Technical Innovation:** Bangladesh's industrial development and technical innovation can be fueled by the use of hybrid energy in EV adoption. Investments in energy storage technology, battery production, renewable energy generation, and infrastructure for electric transportation can open up new markets for home businesses and promote economic expansion. In the rapidly developing worldwide market for electric cars and hybrid energy solutions, Bangladesh may establish itself as a leader by promoting research and development in clean energy and transportation technology.
- **Employment Creation:** In Bangladesh, there may be job openings in a number of industries as a result of the switch to electric vehicles and hybrid energy systems. The transition to clean energy and transportation presents employment opportunities for qualified workers and

entrepreneurs, from the production and assembly of electric vehicles (EVs) and the infrastructure needed for charging them to the installation and upkeep of renewable energy networks. Employment growth and economic development can be further stimulated by government policies and incentives that support the use of renewable energy sources and electric vehicles [42].

- **Better Public Health:** By utilizing hybrid energy to power EV adoption, air pollution from transportation emissions can be reduced, potentially improving public health outcomes in Bangladesh. Electric and hybrid vehicles help lower the rates of respiratory illnesses, cardiovascular disorders, and premature mortality by limiting exposure to dangerous pollutants including particulate matter and nitrogen oxides. In addition to improving people's health and wellbeing, cleaner air quality lowers medical expenses due to illnesses brought on by air pollution.

VII. DISCUSSION

Bangladesh includes a thorough examination of all the variables impacting the nation's adoption, implementation, and integration of hybrid energy and electric vehicle technologies. In order to promote sustainable energy and transportation solutions in Bangladesh, this conversation will look at current issues, suggest possible fixes, and outline upcoming prospects. Currently, Bangladesh lacks an adequate infrastructure for electric vehicle charging, especially in rural and isolated places. Restricted availability of charging stations may discourage the adoption of EVs and impede the shift to electric vehicles. In order to facilitate the EV market's expansion through the use of hybrid energy, infrastructure constraints must be addressed, including the installation of charging stations and grid modifications. Even with the progress made in EV technology, issues including short battery life, lengthy charging durations, and expensive initial expenses continue to exist. Investments in research and development are necessary to overcome technological obstacles in order to create cost-effective EV models that are appropriate for the Bangladeshi market, improve battery performance, and upgrade charging infrastructure [43].

Inadequate legislative backing and regulatory structures may hinder the extensive integration of electric vehicles and hybrid energy systems in Bangladesh. To encourage the purchase of electric vehicles (EVs), integrate renewable energy sources, and encourage investment in sustainable transportation infrastructure, clear rules, incentives, and regulations are required. There are a lot of obstacles since consumers are not aware of or embrace hybrid energy systems and electric vehicles. Many people may be reluctant to convert from conventional automobiles because they are ignorant about EV technology and have false beliefs about electric mobility [44]. To encourage the adoption of electric vehicles (EVs) and build consumer trust in hybrid energy solutions, public awareness campaigns, educational programs, and incentives are required. Financial obstacles prevent the adoption of EVs and the deployment of renewable energy in Bangladesh due to high upfront costs and restricted access to financing options. Incentives, subsidies, and cheap financing for electric vehicle purchases and renewable energy installations can help remove financial obstacles and increase

consumer and company access to hybrid energy and electric mobility [45].

To power EVs responsibly, hybrid energy systems can be combined with Bangladesh's plentiful renewable energy resources, which include hydropower, wind, and solar energy. Bangladesh may mitigate carbon emissions, improve energy security, and foster environmental sustainability by utilizing renewable energy sources including solar-powered charging stations and wind-powered electric vehicle fleets. Bangladesh has bright futures for hybrid energy and electric mobility thanks to ongoing developments in EV technology, battery storage, and renewable energy sources [46]. Innovation in electric mobility and clean energy technologies can be accelerated and costs can be reduced through research and development projects, international partnerships, and technology transfer programs. To accelerate Bangladesh's shift to hybrid energy and electric vehicles, robust legislative support and incentives are required.

In order to secure the effective integration and deployment of electric vehicles (EVs) driven by hybrid renewable energy systems, a number of obstacles and hurdles may arise in the future. The availability and scalability of renewable energy sources, such solar and wind, to fulfill the growing energy needs of EVs on a wide scale is one major hurdle. Creating a constant and dependable charging infrastructure is difficult because to the variability and intermittency of renewable energy supply, especially when output is low. The imbalance between the demand for EV charging and the production of renewable energy also necessitates the development of effective and affordable energy storage systems. Optimizing grid management and charging infrastructure to enable many EVs to be charged simultaneously while reducing the burden on the electrical system is another difficulty. To balance supply and demand and prevent grid congestion, smart charging technologies, grid-responsive charging protocols, and demand-side management techniques must be developed. Furthermore, the broad deployment of hybrid renewable energy systems for EV charging may be hampered by legislative and governmental obstacles like out-of-date infrastructure requirements, a lack of incentives for the integration of renewable energy, and complicated permitting procedures.

Government organizations, utilities, automakers, and developers of renewable energy must work together to solve these issues in order to create policies that support investment in renewable energy and charging infrastructure, expedite regulatory procedures, and encourage investment in these projects. The development of smart charging infrastructure, grid integration techniques, and energy storage technologies will also be essential in improving the scalability, efficiency, and dependability of hybrid renewable energy systems for EV charging. Proactively tackling these obstacles will expedite the shift to renewable energy-powered electric vehicles, thereby mitigating greenhouse gas emissions, enhancing air quality, and augmenting energy security and sustainability.

VIII. CONCLUSION

The case study on Bangladesh's difficulties and potential for electric cars (EVs) using hybrid energy emphasizes the intricate interactions influencing the nation's shift to

sustainable energy and transportation options. Bangladesh has enormous potential to promote electric mobility and hybrid energy integration even in the face of formidable obstacles, such as inadequate infrastructure, technological hurdles, and regulatory restrictions. The problems study emphasizes how critical it is to build infrastructure, innovate technologically, support legislation, raise consumer awareness, and provide financial incentives in order to remove obstacles to the adoption of electric vehicles and the deployment of renewable energy sources. In order to address these issues and establish a supportive environment for sustainable energy and transportation solutions, government society organizations must work together. In addition to offering a roadmap for policymakers, industry stakeholders, and civil society to navigate the transition towards a cleaner, greener, and more sustainable transportation and energy future in the nation, the case study offers insightful information about the opportunities and challenges of electric vehicles using hybrid energy in Bangladesh. Bangladesh can become a pioneer in electric mobility and renewable energy integration by tackling obstacles, seizing possibilities, and encouraging cooperation. This would help the world's efforts to combat climate change and create a more resilient and prosperous future for all.

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