REVIEW ARTICLE

ADOPTION OF ELECTRIC VEHICLES AND RENEWABLE ENERGY CHARGING SYSTEMS IN BANGLADESH: OPPORTUNITIES AND CHALLENGES

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ABSTRACT

Introduction: Embarking on a visionary journey through the bustling thoroughfares of modern Bangladesh, our research paper sets the stage for a narrative where the synergy of Electrical Vehicles (EVs) and renewable charging systems unfolds, painting a canvas of sustainable mobility. This creative odyssey transcends the mundane realms of technological discourse, diving deep into the pulsating heart of the nation where innovation, policy, and socio-economic tapestries converge to shape the trajectory of electric mobility. **Objective**: In this narrative, EVs are not mere vehicles but emissaries of change, heralding a harmonious dance with renewable charging systems. The overarching objective of our study is to meticulously dissect the current landscape of EV adoption, tracing the footprints of progress etched by technology, and policy nuances. The heartbeat of this research lies in the intricate connection between the evolution of renewable charging infrastructure and the unfolding green revolution in transportation. **Methods**: Our study employs a methodical approach, examining the symphony that echoes the accessibility challenges, unraveling the threads that tether us to conventional mobility, and weaving a narrative of possibilities. As we peer into the future, the environmental implications of this electric journey come into focus a tale of how Bangladesh, with its unique energy panorama, aligns EVs with renewable energy sources. **Results**: The paper doesn't merely analyze; it invites stakeholders policymakers, industry visionaries, and the spirited community to join hands in orchestrating a sustainable and electrifying future for mobility in Bangladesh. As a result, our creative synthesis of literature, policy insights, and empirical analysis reveals a compelling story where each decision, each innovation, propels us toward a greener, more electrifying tomorrow. **Conclusion**: In concluding our research, we recognize that this is not just a document; it's a call to co-author a story. A story where each stakeholder becomes a protagonist, actively contributing to a narrative where sustainability and electrification intertwine seamlessly, offering a promising future for mobility in Bangladesh.

Keywords: *Electric vehicle, Solar charging system, Renewable.*

1. INTRODUCTION

Energy stands as a cornerstone for sustainable development, playing a pivotal role in mitigating poverty. In the context of Bangladesh, approximately 77.9% of the overall population enjoys access to electricity. However, the nation's energy landscape is predominantly shaped by conventional fuels, with a heavy reliance on resources like natural gas and coal. Within this energy mosaic, the total power generation capacity in Bangladesh currently amounts to 16,041.73 MW, inclusive of off-grid renewable energy sources. Notably, renewable energy contributes a modest 2.81% to the overall energy portfolio, reflecting both the progress made and the potential for further advancements in sustainable energy practices [1]. The finite nature of natural gas and coal resources in Bangladesh raises concerns about the sustainability of power generation. Recognizing the potential challenges posed by increasing electricity demands, the Government of Bangladesh has proactively initiated measures to address the situation. To diversify the energy mix and enhance resilience, the government aims to implement 2000 MW of renewable energy capacity by the year 2021. Additionally, there is a strategic plan in place to achieve a substantial power generation capacity of 24,000 MW. This ambitious target is intended to meet the growing demand for electricity, and the strategy includes the integration of coal-fired and nuclear power plants in the energy portfolio. These concerted efforts underscore the government's commitment to ensuring a robust and diversified energy infrastructure for the nation's sustainable development [2]. However, the reliance on coal-fired and nuclear power plants, despite addressing energy demands, raises concerns about their environmental impact and the potential harm to our ecosystem. These systems are often associated with adverse effects such as air pollution, greenhouse gas emissions, and long-term environmental degradation. Balancing the need for energy security with the imperative to preserve our environment becomes a critical consideration in steering the nation's energy trajectory. Sustainable and eco-friendly alternatives must be explored and prioritized to ensure a harmonious coexistence between energy development and environmental conservation [3]. As an emerging nation, Bangladesh faces the imperative of strategically planning for the provision of high-quality and reliable electricity to ensure the foundational needs of all its citizens. This commitment to delivering consistent and dependable power is paramount for the nation's envisioned path toward sustainable development.

The planning and execution of robust electricity infrastructure are integral components of fostering economic growth, improving living standards, and ensuring a resilient foundation for the country's overall progress [4]. According to World Bank data spanning from 1971 to 2014, the per capita energy consumption in Bangladesh has shown an upward trend, averaging 131.62 kg of oil equivalent. In 2014, this figure increased to 222.22 kg of oil equivalent, equivalent to 310.39 kWh. Notably, the average percentage contribution of clean energy to the overall energy mix in Bangladesh was 0.42%, a value that rose to 2.86% in 2017. As a developing nation, Bangladesh plays a role in the global greenhouse gas (GHG) landscape, contributing to carbon dioxide (CO2) emissions. Over the period from 1972 to 2014, the average per capita CO2 emissions in Bangladesh stood at 0.46 metric tons, underscoring the country's position as a emitter within the global context [5, 6, 7]. The escalating number of transport vehicles, driven by the burgeoning population in Bangladesh, presents a concerning trend marked by heightened environmental pollution and increased fuel consumption. Amidst this backdrop, there is a notable and encouraging surge in the adoption of Electric Vehicles (EVs), particularly Autorickshaws and Easy Bikes. Unlike their traditional counterparts, these EVs contribute significantly fewer emissions and produce no harmful fumes. However, the lack of comprehensive statistics from the Bangladesh Road Transport Authority (BRTA) regarding these electric vehicles poses a challenge. While some of these vehicles are duly licensed, the available data indicates that the number of registered EVs stands at 2,32,303, accounting for a portion of the total vehicle count of 26,40,349. This evolving landscape signifies a positive shift towards sustainable and eco-friendly transportation alternatives [8]. Nevertheless, the rapid surge in the adoption of Electric Vehicles (EVs) in Bangladesh comes with an increased demand for electricity, necessitating an additional daily supply of more than 500 MW from the national grid. This growing energy requirement underscores the importance of simultaneously enhancing the capacity of the national grid infrastructure to accommodate the expanding fleet of EVs and advancing renewable energy solutions to ensure a sustainable and resilient power ecosystem [9,10]. Electric Vehicles (EVs) are being charged in residential areas, and the associated electricity bills are borne by residential consumers. However, this paradigm poses a challenge for the power sector, as it does not yield any profit from the charging of these EVs. Concurrently, the increasing number of EVs is exerting substantial pressure on the national grid of Bangladesh. To alleviate this strain on the grid and explore a cost-effective alternative, there is a pressing need for innovative approaches to electricity generation. This imperative calls for strategic interventions that not only address the challenges posed by EV charging but also contribute to the overall sustainability and efficiency of the national power system [11]. Bangladesh possesses abundant renewable energy resources such as solar, biogas, and biomass, offering a viable avenue for power generation. Harnessing energy from these renewable sources not only results in reduced CO2 emissions but also entails lower operational costs, contributing to environmental cleanliness. Unlike conventional systems, renewable energy setups do not necessitate monthly billing. Leveraging renewable energy resources for Electric Vehicle (EV) charging not only enhances commercial efficiency but also has a positive impact on air quality, mitigating noise pollution in urban areas. This strategic alignment underscores the multifaceted benefits of integrating renewable energy into the charging infrastructure for EVs in Bangladesh [12]. Given its abundant solar energy resources, solar power emerges as the optimal choice for electricity production to charge Electric Vehicles (EVs) in Bangladesh. The Bangladesh Rural Electrification Board (BREB) has taken a pioneering step by installing a 21 kW Solar Charging Station (SCS) in Keranigonj. Additionally, the Bangladesh Power Development Board (BPDB) has made strides in this direction by establishing two SCSs in Chittagong and one in Sylhet, each with a power-generating capacity of 20 kW. Notably, these Solar Charging Stations have the capability to simultaneously charge 20–25 Easy Bikes, representing a significant leap toward sustainable and solar-powered EV charging infrastructure in the country [13]. Nevertheless, the dependence solely on solar energy for charging Electric Vehicles (EVs) poses challenges during rainy days and in foggy environments, where solar irradiation is absent, leading to a halt in energy production. This reliance on solar energy alone may jeopardize the system's reliability, potentially resulting in project failures. To address this vulnerability and enhance resilience, there is a crucial need to integrate alternative energy sources such as biogas and biomass. These complementary sources offer a reliable and continuous energy supply, ensuring uninterrupted electricity production for EV charging even in conditions where solar energy is unavailable.

2. MATERIALS AND METHODS

2.1 Data Collection

Extensive literature review was conducted to collect secondary data from published reports, journal articles, conference papers, government databases, and websites of relevant organizations etc. related to:

- Energy scenario, policies and statistics in Bangladesh,
- Growth of electric vehicles,

- Charging infrastructure and technologies,
- Environmental impacts.
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Key secondary data sources included:

- Sustainable and Renewable Energy Development Agency (SREDA),
- Bangladesh Power Development Board (BPDB),
- Bangladesh Road Transport Authority (BRTA),
- World Bank Database.

2.1 Primary Data

Structured interviews and surveys were conducted with relevant stakeholders to obtain primary data and insights on:

- Current adoption levels of EVs,
- Charging and operational practices,
- Government regulations and policies,
- Future growth projections and infrastructure needs.

3. RESULTS AND DISCUSSION

3.1 Electric Vehicle Current status in Bangladesh

Battery-operated electric vehicles (EVs) made their debut in Bangladesh in 2009 and have since become ubiquitous across the nation. These EVs, categorized as Easy Bikes (carrying 4–5 passengers), Auto-rickshaws (transporting 2 passengers), and Electric rickshaw vans (hauling goods), have gained popularity for their eco-friendly nature and minimal noise and fume emissions. Initially imported from China, domestic companies now produce these vehicles. A fully charged Easy Bike covers approximately 80–100 km, costing around one lac twenty thousand BDT, while Auto-rickshaws and Electric rickshaw vans, priced at sixty thousand BDT, can travel 50–70 km on a full charge. The market has witnessed a shift from imports to local production. A fully charged EV travels 80–100 km per day, consuming 8–11 kWh, with an operational cost of approximately 1.35 BDT per km. Solar charging stations, operated by the Bangladesh Rural Electrification Board (BREB), have been established, contributing to the growing popularity of EVs. Despite energy consumption challenges, EVs have brought a revolutionary change to the transportation sector, especially in sub-rural and rural areas, offering affordable fares and enhancing the overall well-being of low-income individuals, including drivers. Private initiatives have introduced electric-powered Easy Bikes and Auto-rickshaws, gaining popularity in rural and peri-urban areas. However, concerns about energy consumption from the national grid persist, prompting ongoing efforts to alleviate the grid's burden and enhance charging infrastructure. A survey conducted in Trishal upazilla revealed the dominance of battery-driven EVs, primarily charged from residential connections, presenting both challenges and opportunities for future development in Bangladesh's evolving transportation landscape.

3.2 Charging System

Electric Vehicles (EVs) equipped with bidirectional (two-way) charging capability present a transformative innovation in the realm of sustainable energy. These vehicles, essentially large batteries on wheels, have the potential to not only revolutionize personal transportation but also redefine the dynamics of energy consumption and distribution. Bidirectional chargers, a key component of this emerging technology known as Vehicle-to-Grid (V2G), empower EVs to serve as more than just modes of transportation. They enable these vehicles to store inexpensive off-peak electricity or harness solar power, thereby contributing to the reduction of household electricity costs. This dual functionality of EVs, as mobile energy storage units and transportation devices, opens avenues for enhanced energy efficiency and cost-effectiveness. Moreover, the bidirectional charging capability allows EVs to act as energy hubs for homes, offering the possibility of powering residences, feeding surplus energy back into the electricity grid, and serving as backup power sources during blackouts or emergencies. This multifaceted role positions EVs as integral components of a dynamic and resilient energy ecosystem.The potential impact of V2G technology extends beyond individual households. Tens of thousands of electric vehicles, synchronized through bidirectional chargers, have the capacity to supply power simultaneously during peak electricity demand periods. This collective contribution can significantly influence the stability and efficiency of power grids, paving

the way for a more sustainable and responsive energy infrastructure.As V2G technology continues to advance, the integration of bidirectional charging capabilities in EVs holds promise for shaping a future where electric vehicles play a pivotal role not only in transportation but also in the broader context of energy management and grid resilience. This paradigm shift underscores the transformative potential of EVs in reimagining the relationship between mobility and energy sustainability [14]. Figure 1 A bidirectional charger represents a sophisticated advancement in Electric Vehicle (EV) charging technology, introducing the capability of two-way charging. While the concept might seem straightforward, the execution involves a complex power conversion process, transitioning between Alternating Current (AC) and Direct Current (DC). This sets bidirectional chargers apart from conventional unidirectional EV chargers, which exclusively facilitate one-way charging using AC. In contrast to standard EV chargers, bidirectional chargers operate akin to inverters, performing the intricate task of converting AC to DC during charging and vice versa during discharging. However, it's important to note that bidirectional chargers are compatible only with a select number of EVs designed for two-way DC charging. Presently, a limited range of EVs, with the Nissan Leaf being a notable example, supports bidirectional charging. Due to their heightened complexity, bidirectional chargers also come with a higher price tag compared to regular EV chargers, incorporating advanced power conversion electronics to manage the bidirectional flow of energy to and from the vehicle. In scenarios where bidirectional EV chargers supply power to a home, they integrate specific equipment to handle loads and isolate the house from the grid during an outage. This isolation, known as islanding, ensures that the home remains powered even when the external grid faces disruptions. The fundamental operational principle of bidirectional EV chargers shares similarities with bidirectional inverters, a technology that has been employed in home battery storage systems for backup power for over a decade. This confluence of bidirectional charging and home power management signifies a significant stride toward creating resilient and versatile energy systems.

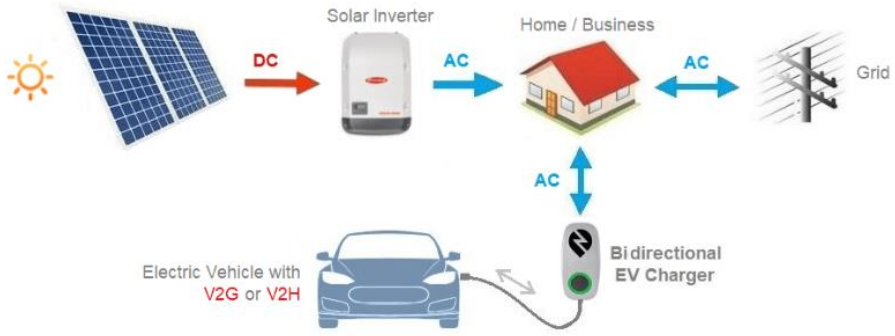

Figure 1: Electric Vehicle Charging System [14].

3.3 Grid Hybrid Renewable Energy-Based Electric Vehicle Charging Station

The concept delineates a grid-connected hybrid electric vehicle charging station integrating diverse energy sources. A 10Kw solar photovoltaic (PV) panel, monitored by a Maximum Power Point Tracker (MPPT), harnesses solar energy. Three biogas generators, fueled by animal waste like cow dung, poultry waste, and municipal solid waste (MSW), enhance power generation. A charge controller ensures optimal voltage and current for battery charging, stopping when batteries are full and redirecting excess power to a bidirectional converter for DC to AC conversion. During hybrid power unavailability, the national grid supplements power, especially during off-peak periods. Surplus energy can be sold back to the national grid. Electric vehicles connect to the AC bus through a charging apparatus. The economic feasibility analysis involves expressing the 10 kW solar PV module and total 10 kW biogas-generated power in financial terms. Net Present Cost (NPC) considers installation and replacement costs, while Operational and Maintenance (O&M) costs areassessed for the system's lifespan. Return on investment is measured by the payback period and annual cash flow summary, with the Profitability Index (PI) determining the feasibility of the proposed charging station. This comprehensive approach ensures sustainable, economically viable operations, aligning with goals of renewable energy adoption and electric vehicle charging infrastructure for Figure 2.

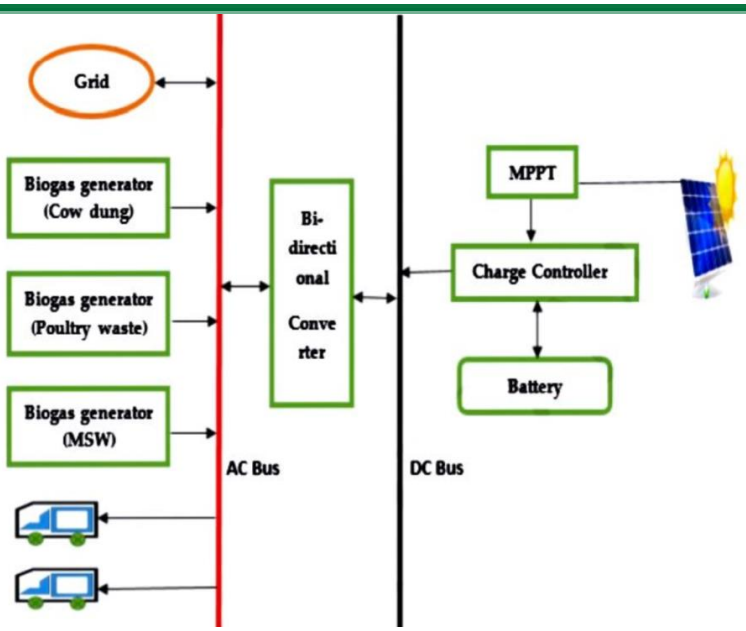

Fig 2: Grid Connected Hybrid Renewable Energy-Based EVCS [15].

It is assumed that an electric vehicle is in use for 26 days per month, consuming an average of 12 kWh daily to cover a distance of 80 km, resulting in a requirement of 0.15 kWh electric power per kilometer traveled. The monthly electric bill for charging the electric vehicle amounts to about 3050 BDT ($38.12). Given that solar radiation is available for electricity production only 5 to 6 hours a day, solar energy can generate power only during these hours. In contrast, biogas generators can be operational for 6–8 hours daily. The calculation of economic parameters is detailed in Table 1. This analysis provides insights into the cost-effectiveness and efficiency of the proposed hybrid electric vehicle charging station, considering energy consumption patterns and available resources.

Table 1: The table presents the calculation of the economic parameters [16,17,18].

Active Hours (kWh/Year)	Energy Production (Year)	Lifetime (Year)	Annual Cash Flow ($)	Payback Period (Year)	Profitability Index (PI)
5-6	15,350	25	$188	10.1	>1
6-8	10,220	5	$125	3.02	
6-8	9490	5	$116	3.1	
6-8	5110	5	$626	3.72	

Figure 2 we can say that the annual cash flow analysis, categorized by resource type, reveals that PV contributes the highest amount to energy generation, followed by Bio 1, Bio 2, and Bio 3. In evaluating the financial feasibility of the charging station project, the profitability index is greater than one. This result suggests that the project is economically viable and holds financial merit. The profitability index serves as a crucial metric, indicating the potential success and sustainability of the proposed hybrid electric vehicle charging station.

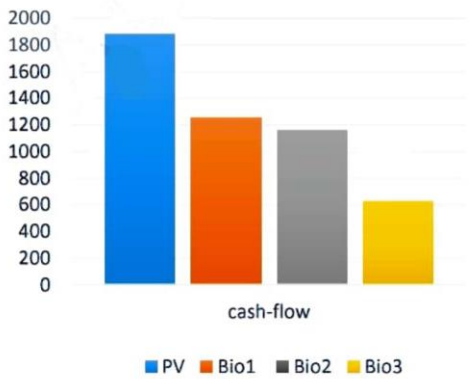

Figure 2: Annual cash flow by resources [15].

3.4 Difference between Solar charging and Non-renewable charging in Electrical Vehicle

Charging electric vehicles (EVs) through solar panels and non-renewable sources yields distinctive differences in environmental impact, cost, sustainability, and reliability. Solar panel charging exemplifies environmental friendliness by harnessing energy from the sun, a renewable resource, thereby minimizing direct emissions and reducing the carbon footprint associated with traditional energy sources. Although the initial investment for solar panels can be substantial, their operational costs are comparatively low, offering potential long-term savings as technology advances. This approach promotes sustainability by reducing dependence on finite fossil fuels, contributing to energy security in the long run. However, solar charging's intermittency due to sunlight availability necessitates energy storage solutions like batteries for consistent power supply. Conversely, non-renewable charging, reliant on fossil fuels, poses environmental concerns with associated emissions and finite resource depletion. While non-renewable sources offer more consistent and reliable energy, they lack the sustainability and long-term benefits associated with solar panel charging. Ultimately, solar charging emerges as a cleaner, more sustainable, and potentially cost-effective solution, aligning with the growing emphasis on environmentally conscious transportation alternatives.

Table 2: The presents the difference between Solar charging and Non-renewable charging in Electrical Vehicle [16,17,18].

Feature	Solar Panel Charging	Non-Renewable Charging
Energy Source	Sun's sunlight	Fossil fuels (coal, natural gas, oil)
Environmental Impact	Zero emissions, renewable	Generates greenhouse gases, non-renewable
Cost	Variable, depends on upfront installation cost and local electricity rates	Fixed, based on electricity rates
Dependency	Self-reliant, not dependent on external energy sources	Dependent on external energy sources
Reliability	Weather-dependent, less reliable in low sunlight conditions	Consistent supply, reliable in most conditions
Maintenance	Minimal maintenance required	Requires regular maintenance of power plants
Scalability	Can be easily scaled up or down based on needs	Limited scalability, requires significant infrastructure investment
Overall Sustainability	Highly sustainable, reduces reliance on fossil fuels	Less sustainable, contributes to climate change

3.5 Environmental Impacts difference between solar panel charging and non-renewable charging in the electrical vehicle

The environmental impacts of solar panel charging and non-renewable charging for electric vehicles differ significantly. Solar panel charging offers advantages such as reduced carbon footprint, clean energy production, and the renewability of resources. However, challenges include the environmental impact of manufacturing solar panels and potential land use issues for large-scale installations. On the other hand, non-renewable charging, primarily relying on fossil fuels, comes with established infrastructure and high energy density but contributes significantly to greenhouse gas emissions, resource depletion, and environmental degradation through processes like oil spills and coal ash disposal. The choice between the two reflects the broader shift toward sustainable and cleaner energy sources to mitigate environmental impacts.

Table 2: Environmental Impacts of solar panel charging and non-renewable charging in the electrical vehicle.[16,17,18]

Environmental Impact	Solar Panel Charging	Non-Renewable Charging
Greenhouse Gas Emissions	Zero greenhouse gas emissions	Significant greenhouse gas emissions, primarily carbon dioxide
Air Pollution	No air pollution	Contributes to air pollution, including particulate matter, nitrogen oxides, and sulfur dioxide
Water Pollution	No water pollution	Can cause water pollution from mining, refining, and transporting fossil fuels
Land Use	Requires minimal land for solar panel installation	Requires extensive land for fossil fuel extraction and power plant construction
Resource Depletion	Uses renewable solar energy	Depletes finite fossil fuel resources

4. CONCLUSION

Embarking on a visionary exploration of the symbiotic relationship between Electric Vehicles (EVs) and renewable charging systems in contemporary Bangladesh, this research unfolds a narrative of sustainable mobility. EVs transcend mere transportation, emerging as catalysts for change intricately entwined with renewable charging systems. Navigating through technological progress, policy intricacies, and socio-economic fabrics, the paper dissects the evolving landscape of electric mobility, emphasizing the environmental implications of solar panel charging versus non-renewable charging for EVs. Bangladesh's energy panorama, predominantly shaped by conventional fuels, prompts the government's proactive measures to diversify the energy mix and enhance resilience, underscoring the pivotal role of renewable energy in sustainable development. The proposal introduces a grid-connected hybrid renewable energy-based electric vehicle charging station, economically viable according to the profitability index. Distinguishing between solar panel and non-renewable charging, the paper outlines differences in environmental impact, cost, sustainability, and reliability, positioning solar charging as a cleaner, more sustainable solution in the global shift toward environmentally conscious transportation. Ultimately, this research is a call to co-author a story where decisions and innovations collectively propel Bangladesh toward a greener, more electrifying tomorrow, urging stakeholders to orchestrate a sustainable future for mobility. As a compass in the evolving landscape of energy evolution, the paper envisions a future where Electric Vehicles and renewable charging systems dance together in a symphony of sustainability.

5. REFERENCE

1. Sustainable and Renewable Energy Development Agency (SREDA), Bangladesh. Available from: www.sreda.gov.bd. Accessed October 9, 2023.
2. Bangladesh Power Development Board (BPDB), Bangladesh. Available from: www.bpdb.org.bd. Accessed October 9, 2023.
3. Hossain MA, Hossain MZ, Rahman MA. Perspective and Challenge of Tidal Power in Bangladesh. *World Acad Sci Eng Technol.* 2014;8:1140-3.
4. Ahiduzzaman M, Sadrul Islam AKM. Greenhouse gas emission and renewable energy sources for sustainable development in Bangladesh. *Renew Sustain Energy Rev*. 2011;15:4659-66.
5. Per capita energy consumption and Share of clean energy. Available from: http://www.theglobaleconomy.com/Bangladesh/Share_of_clean_energy/. Accessed September 14, 2023.
6. Sarkar MS, Sadeka S, Sikdar MM, Zaman B. Energy Consumption and CO2 Emission in Bangladesh: Trends and Policy Implications. *Asia Pac J Energy Environ*. 2015;2:175-82.
7. CO2 emissions (metric tons per capita). Available from: https://data.worldbank.org/indicator/en.atm.co2e.pc?locations=bd. Accessed October 12, 2023.
8. Number of registered motor vehicles in Bangladesh. Available from: http://www.brta.gov.bd/newsite/wpcontent/uploads/2016/07/statistics-bangladesh-june16.pdf. Accessed September 14, 2023.
9. PDB bringing battery run vehicles tariff regulations. Available from: http://www.dhakatribune.com/bangladesh/power-energy/2017/09/27/pdb-bringing-battery-run-vehicles-tariffregulations/. Accessed September 14, 2023.
10. Deb A, Bhuiyan MAM, Nasir A. Prospects of Solar Energy in Bangladesh. *IOSR J Electr Electron Eng*. 2013;4(5):46-57.
11. Islam MM, Das NK, Ghosh S, Dey M. Design and implementation of cost-effective smart solar charge station. In: Proceedings of the 2014 9th IEEE International Forum on the Strategic Technology (IFOST). 2014 Oct 21. p. 339-42.
12. Yousuf SA, Venayagamoorthy GK. Plug-in vehicles and renewable energy sources for cost and emission reductions. *IEEE Trans Ind Electron*. 2011;58:1229-38.
13. International Renewable Energy Agency (IRENA). Biogas for Road Vehicles: Technology Brief. Abu Dhabi: IRENA; 2017.
14. Svarc J. Bidirectional EV charging explained - V2G, V2H & V2L. Clean Energy Reviews [Internet]. 2023 Nov 11 [cited 2023 Feb 26]; Available from: https://www.cleanenergyreviews.info/blog/bidirectional-ev-charging-v2g-v2h-v2l
15. Karmaker AK, Ahmed MR, Ma H, Sikder MM. Feasibility assessment & design of hybrid renewable energy-based electric vehicle charging station in Bangladesh. *Sustain Cities Soc.* 2018;39:189-202.
16. Energy.gov [Internet]. Available from: https://www.energy.gov/.
17. Hemp M. Benefits of Biogas. American Biogas Council [Internet]. 2023 Jun 30 [cited 2023 Feb 26]; Available from: https://americanbiogascouncil.org/resources/why-biogas/.
18. U.S. Solar Market Insight. SEIA [Internet]. Available from: https://www.seia.org/us-solar-market-insight.
1. Sustainable and Renewable Energy Development Agency (SREDA), Bangladesh. [Online]. Available: www.sreda.gov.bd (Accessed: 22 September 2023).
2. Bangladesh Power Development Board (BPDB), Bangladesh. [Online]. Available: www.bpdb.org.bd (Accessed: 22 September 2023).
3. Hossain, M.A.; Hossain, M.Z.; Rahman, M.A. Perspective and Challenge of Tidal Power in Bangladesh. World Academy of Science. *Eng. Technol*. 2014, 8, 1140–1143.
4. Ahiduzzaman, M.; Sadrul Islam, A.K.M. Greenhouse gas emission and renewable energy sources for sustainable development in Bangladesh. *Renew. Sustain. Energy Rev*. 2011, 15, 4659–4666.
5. Per capita energy consumption and Share of clean energy. [Online]. Available: http://www.theglobaleconomy.com/Bangladesh/Share_of_clean_energy/ (Accessed: 14 September 2023).
6. Sarkar, M.S.; Sadeka, S.; Sikdar, M.M.; Zaman, B. Energy Consumption and CO2 Emission in Bangladesh: Trends and Policy Implications. *Asia Pac. J. Energy Environ.* 2015, 2, 175–182.
7. CO2 emissions (metric tons per capita). [Online]. Available: https://data.worldbank.org/indicator/en.atm.co2e.pc?locations=bd (Accessed: 12 October 2023).
8. Number of registered motor vehicles in Bangladesh. [Online]. Available on: http://www.brta.gov.bd/newsite/wpcontent/uploads/2016/07/statistics-bangladesh-june16.pdf (Accessed: 14 September 2023).
9. PDB bringing battery run vehicles tariff regulations. [Online]. Available: http://www.dhakatribune.com/bangladesh/power-energy/2017/09/27/pdb-bringing-battery-run-vehicles-tariffregulations/ (Accessed: 14 September 2023).
10. Anik Deb, Dr. Mahmud Abdul Matin Bhuiyan, Arefin Nasir "Prospects of Solar Energy in Bangladesh," IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676 Volume 4, Issue 5 (Jan. - Feb. 2013), PP 46-57.
11. Islam, M.M.; Das, N.K.; Ghosh, S.; Dey, M. Design and implementation of cost-effective smart solar charge station. In Proceedings of the 2014 9th IEEE International Forum on the Strategic Technology (IFOST), Cox's Bazar, Bangladesh, 21 October 2014; pp. 339–342.

12. Yousuf, S.A.; Venayagamoorthy, G.K. Plug-in vehicles and renewable energy sources for cost and emission reductions. *IEEE Trans. Ind. Electron*. 2011, 58, 1229–1238.
13. International Renewable Energy Agency (IRENA). Biogas for Road Vehicles: Technology Brief; International Renewable Energy Agency: Abu Dhabi, Arab Emirates, 2017.
14. Svarc, J. (2023, November 11). Bidirectional EV charging explained - V2G, V2H & V2L — Clean Energy Reviews. CLEAN ENERGY REVIEWS. Avalable on : https://www.cleanenergyreviews.info/blog/bidirectional-ev-charging-v2g-v2h-v2l
15. Karmaker, A. K., Ahmed, M. R., Ma, H., & Sikder, M. M. (2018). Feasibility assessment & design of hybrid renewable energy-based electric vehicle charging station in Bangladesh. *Sustainable Cities and Society*, *39*, 189–202. https://doi.org/10.1016/j.scs.2018.02.035
16. *Energy.gov*. (n.d.). https://www.energy.gov/
17. Hemp, M. (2023, June 30). *Benefits of Biogas | American Biogas Council*. American Biogas Council. https://americanbiogascouncil.org/resources/why-biogas/
18. *U.S. Solar Market Insight | SEIA*. (n.d.). SEIA. Avalable on : https://www.seia.org/us-solar-market-insight

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