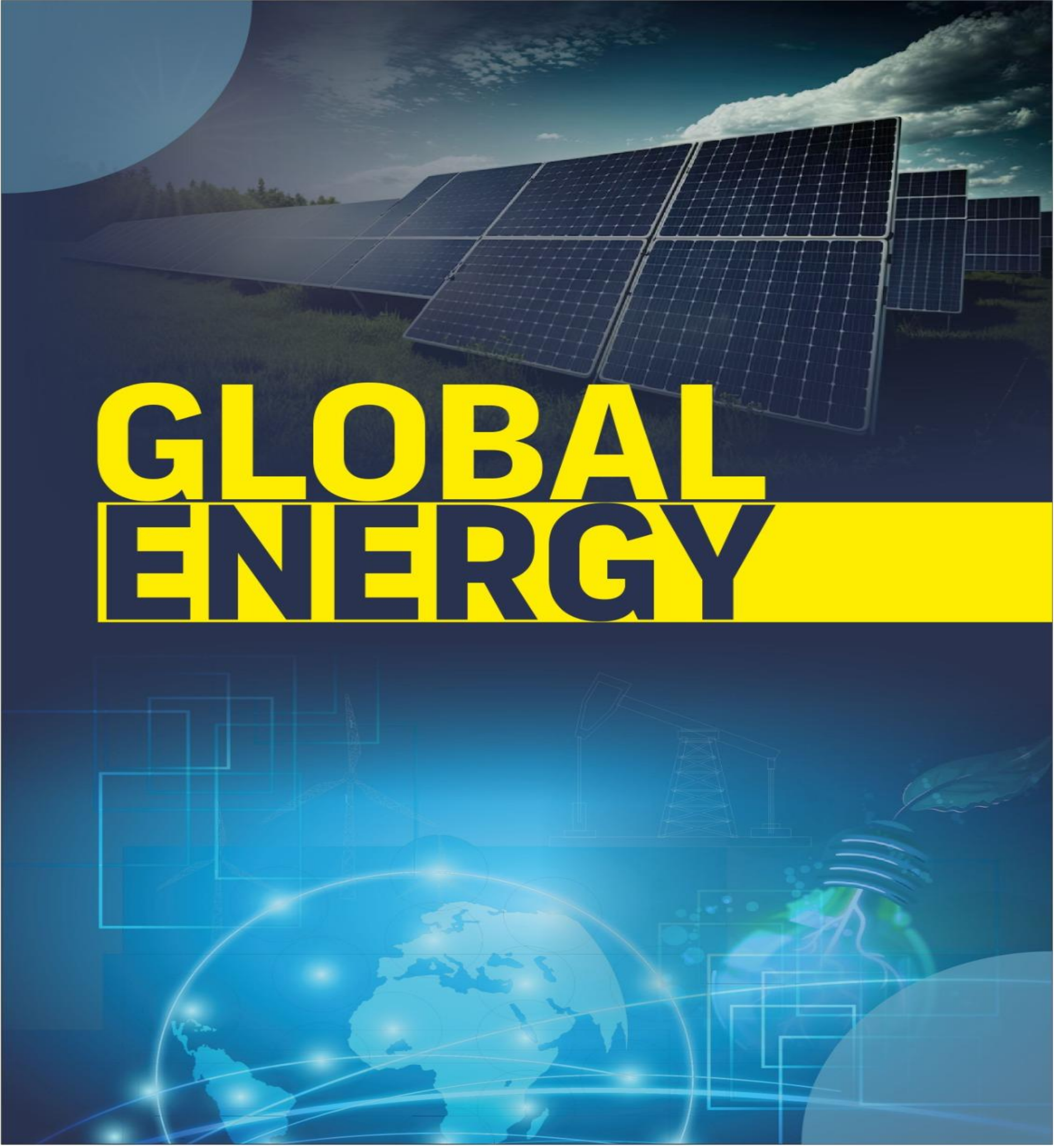

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An Analysis on the Integration of Electric Vehicles into Power Systems and Vehicle-to-Grid (V2G) Applications

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ABSTRACT

The global energy sector is undergoing a significant transformation in line with sustainability goals. The increasing use of renewable energy sources requires more flexible and dynamic management of energy systems. Electric vehicles (EV) play an important role in this transformation, and their interactions with energy power systems present new opportunities and challenges. In order to examine the impacts of EV on energy systems and their contributions to demand forecasting processes, V2G (vehicle to power system) and G2V (power system to vehicle) technologies are comprehensively addressed. The ability of EVs to feed their batteries back into the power system offers significant advantages in terms of balancing the power system and integrating renewable energy sources. V2G technology can balance energy demand by providing flexibility to power systems and provide resistance to demand fluctuations. G2V applications can reduce the load on the power system by providing better planning and management of energy consumption. Accurate demand forecasting is critical for the effective management of energy systems. Demand forecasting optimizes power system management by predicting changes in energy consumption. V2G and G2V technologies can increase the accuracy of these estimates with data obtained from energy consumption and charge/discharge cycles. As a result, this study aims to contribute to the development of sustainable solutions in energy management by evaluating the potential contributions of V2G and G2V technologies on the power systems of electric vehicles connected to a feeder with intensive energy consumption in Batman province and the integration of these technologies into demand forecasting methods.

1. Introduction

In recent years, modern power systems have undergone significant changes in various aspects due to technical, economic, and environmental factors. One of the most notable issues is the focus of energy policies on low-carbon emissions as a response to climate change. It has been observed that renewable energy sources have been substantially integrated into power systems in recent years, introducing new challenges regarding the stability and security of power systems. Electric vehicles (EVs) play a crucial role in power systems due to their significant mobility and flexibility characteristics. Currently, the increasing penetration of renewable energy sources into modern power systems is evident, providing numerous benefits for mitigating climate change and accelerating the transition to low-carbon energy. However, the intermittent and unstable nature of renewable energy sources introduces new challenges for both the planning and operation of power systems.

Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) technologies can provide various ancillary services to support stable and secure power system operations. EVs are being increasingly integrated into modern power systems, contributing to the utilization of clean energy. The large-scale integration of EVs into power systems offers benefits for low-carbon transitions and enhances power system stability [1].

It is anticipated that the adoption of EVs in the transportation sector will increase significantly. While V2G technology offers numerous advantages by enabling vehicles to interact efficiently with smart grids, its widespread adoption will increase energy demand and create challenges for load management in power systems. EV users face challenges such as charging costs, charging duration, and access to public charging infrastructure. As the gradual widespread implementation and adoption of EVs continue, a significant increase in overall power demand, particularly during morning commuting hours, is expected. Simultaneous large-scale charging of EVs can lead to system overloads, voltage drops, and, in extreme cases, power system failures. Additionally, the synchronous initiation and termination of EV charging stations can cause frequency fluctuations within electric power systems.

On the power system side, it is necessary to meet the electricity demand by increasing the power supply capacity during peak hours or by adopting demand response strategies that can control the capacity of the power system, posing challenges for the construction and operation of infrastructure capable of managing system capacity. Specific measures may include increasing transformer capacities, reinforcing distribution lines, and constructing new substations. However, such measures will increase the investment costs associated with power systems.

Considering these issues, we propose that EVs can be utilized as distributed energy resources in discharge mode to supply reverse power to the grid through V2G technology. During peak load demand periods, EVs can feed stored energy back into the grid, thereby not only reducing the load pressure on the power system but also serving as an emergency response mechanism. This article proposes an approach that leverages V2G technology by planning EV charging and discharging activities during parking to reduce the daily energy costs for EV users while addressing energy demand management challenges in power systems [2, 3, 4, 5].

2. GENERAL STRUCTURE OF ELECTRIC VEHICLES,

All vehicles equipped with electric motors are classified as electric vehicles (EVs). In the design of EVs, energy generation and distribution are performed through the drive system components integrated into the vehicle. EV technologies include models where the electric motor receives its entire required energy from the battery, hybrid EV models, and fuel cell EV models with or without auxiliary batteries [6, 7].

Hybrid Electric Vehicles (HEVs) are equipped with both an internal combustion engine and an electric motor, providing propulsion collaboratively. The batteries of HEVs are charged during driving and cannot be charged via external sources [6, 7].

Plug-in Hybrid Electric Vehicles (PHEVs) are similar to HEVs in having both an electric motor and an internal combustion engine. The key distinction from HEVs is that PHEVs can be charged not only through regenerative means but also by connecting to charging stations. Due to their capability to connect to power systems, PHEVs have an impact on power systems [7, 8].

Battery Electric Vehicles (BEVs) operate entirely on electricity and are designed with only an electric motor instead of an internal combustion engine. The electric motor's energy requirements are supplied by batteries, and the motion generated by the motor is transferred to the wheels through the drivetrain. The range of BEVs varies proportionally with the capacity of their batteries. Supercapacitors or secondary batteries can be used to support the main battery in BEVs. Given their limited range and sole reliance on electricity, EV charging stations are critical for BEV users [9].

Fuel Cell Electric Vehicles (FCEVs) utilize fuel cell systems powered by hydrogen-filled tanks, producing electricity rather than consuming it from a battery, unlike BEVs. They incorporate a fuel storage system, a fuel cell control unit, a power processor unit, and a drive system. Their low emissions, energy efficiency provided by fuel cells, and rapid refueling capabilities are among their significant advantages [8, 9].

2.1. Charging Methods of Electric Vehicles

EVs chemically store electrical energy obtained from the power system in their batteries, which is later converted back into electricity to enable vehicle movement. A critical aspect of energy storage in EVs is the speed of the charging process, which depends on the battery capacity, power system infrastructure, and the electronic circuits managing the charging control. EV batteries require periodic charging either through residential charging equipment or charging stations. EV charging units and types are utilized for the charging process, with variations among charging equipment based on the type of supply current and voltage. Charging processes are categorized into three levels, described as follows [7, 10]:

2.1.1. Level 1

This is the slowest charging method for EVs, using single-phase electrical supply at residences and parking areas without requiring additional infrastructure. It is an accessible and cost-effective method.

2.1.2. Level 2

This method provides moderate charging speed for EVs, using single-phase or three-phase electrical supply at private or public facilities. It allows for approximately three times the current of Level 1 charging, requiring additional infrastructure.

2.1.3. Level 3

This is the fastest charging method for EVs, implemented at fuel stations, rest areas, or dedicated charging points outside urban centers, requiring substantial infrastructure investments [7, 10].

2.2. Impact of Electric Vehicles on Power Systems

Energy demand holds significant importance, particularly in developing countries, as continuous and uninterrupted energy supply is essential for economic sustainability. The increasing energy demand driven by technological advancements necessitates growing investments in the energy sector. Discrepancies between forecasted and actual values in load forecasting for electrical power systems can impact future power system planning. If energy demand exceeds planned levels, energy distribution companies may need to implement interruptions to maintain energy balance, negatively affecting the production capabilities of large-scale industrial operations. Conversely, lower-than-expected energy demand may lead to unnecessary infrastructure investments, emphasizing the need for accurate load forecasting [7].

The rise of EV technologies in recent years has increased the demand for electricity from power systems. Given that EVs generally have shorter ranges than internal combustion engine vehicles, they require longer charging periods within the existing power system, adding additional loads as their adoption expands. Considering human vehicle usage patterns, managing charging processes during peak and daytime hours can help balance energy supply and demand. However, rapid charging during peak hours can damage power system components. The connection of different numbers of EVs to various phases and their distinct power demands can cause phase imbalances, current and voltage harmonics, and subsequently power quality issues. To mitigate these adverse effects, utilizing V2G technology with EVs can generate positive impacts on power systems and contribute to balancing energy supply and demand [7, 11].

2.3. Integration of Charging Stations into Power Systems

Electric motors in EVs require electrical energy to function, necessitating charging processes. There are two primary methods for integrating EVs into power systems [7]:

2.3.1. Grid-to-Vehicle (G2V)

In this method, EVs and HEVs store electrical energy in their batteries by receiving power from the power systems. As EV batteries operate on DC voltage, AC/DC converters are required for charging from AC power systems. Subsequently, DC/DC converters adjust voltage levels to the required values to ensure balanced energy storage within the battery cells. This method provides unidirectional energy transfer from the power system to EV batteries [7, 9, 10].

2.3.2. Vehicle-to-Grid (V2G)

In this energy transfer method, EVs integrated into the power system supply energy back to the grid. This capability applies to EVs and HEVs with batteries, allowing them to transfer stored electrical energy back to the power system, providing reverse energy flow using DC/DC converters within EVs. These converters also correct the power factor during V2G energy transfer. Given the typically low usage of EVs during nighttime, energy storage during these hours can prevent excessive loading of the power system, while discharging stored energy during peak hours can significantly balance energy supply and demand. For this process to be feasible, the following conditions must be met:

EVs must support bidirectional energy transfer.
EVs must be capable of communicating with the power system.
EVs must have electronic control circuits capable of calculating battery state of charge.

Only EVs are suitable for supplying energy back to the power system, as HEVs are not utilized in V2G applications due to their lower battery capacities [9, 10, 11].

3. Material and Method

An 11 kW AC charging station was installed on a city feeder characterized by high energy consumption density. Through the use of energy analyzers, 24 hourly energy consumption values per day and a total of 720 monthly values were obtained for the city feeder throughout the year 2024. In this study, datasets were constructed for the first nine months of 2024, and analyses were conducted accordingly.

As presented in Figure 1, the monthly energy consumption data for 2024 indicate that the highest consumption was recorded in August, with a total of 6.210 MW, while the lowest consumption was observed in April, with a total of 3.372 MW. Figure 2, which details the monthly energy consumption values for the first nine months of 2024, shows that within August, which had the highest overall consumption, the peak daily energy consumption occurred on the 29th day of the month.

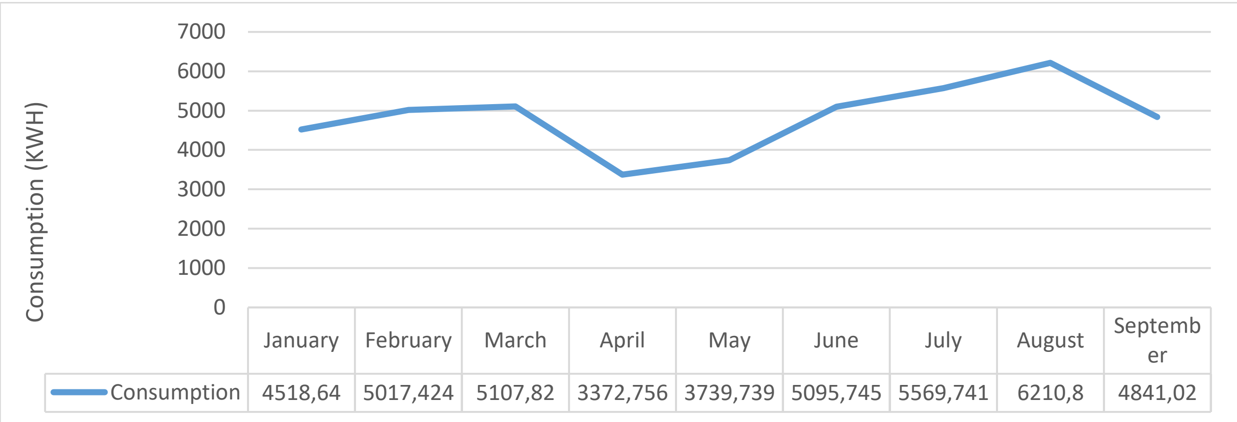

Figure 1: Monthly Energy Consumption of the City Feeder in 2024

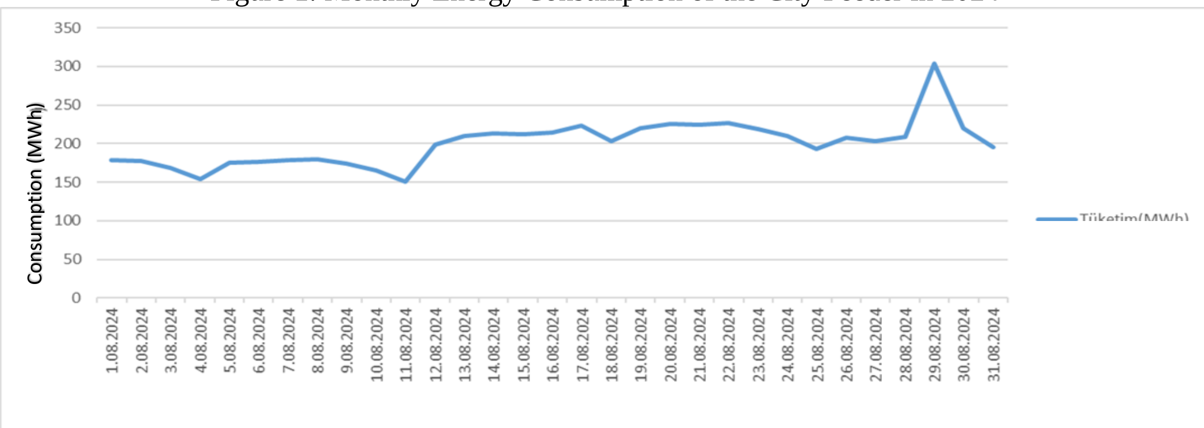

Figure 2: Daily Energy Consumption of the City Feeder in August 2024

Hourly energy consumption data for the day with the highest energy usage in August are examined in **Figure 3**. As shown in Table 3, energy consumption is concentrated between 10:00 AM and 9:00 PM. This indicates that energy intensity increases during daytime and peak hours.

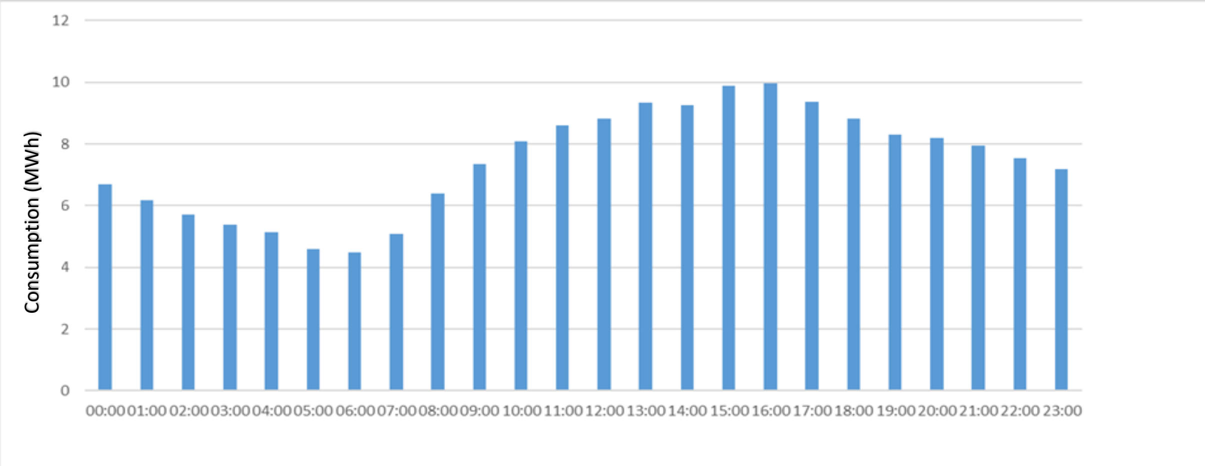

Figure 3: Daily Energy Consumption of the City Feeder in August 2024

A Nissan Leaf e+ vehicle, equipped with a 62 kWh battery and supporting AC charging at an 11 kW charging station, has an approximate charging duration of 10 hours. According to Table 3, energy can be stored in the EV's battery during the low-demand period between 12:00 AM and 9:00 AM. During the high-demand period between 10:00 AM and 9:00 PM, EVs can supply energy back to the power system, thereby balancing energy supply and demand.

Specifically, when vehicles are charged during nighttime hours—when the power system is under lower load and vehicles are parked—additional load on transformers due to EV charging will be avoided during daytime and peak periods, allowing the power system to be managed more effectively. By utilizing V2G technology to transfer the energy stored in EVs back to the power system during daytime and peak demand periods, it is possible to balance energy supply and demand efficiently.

4. Conclusion

The transformation occurring within the global energy sector is accelerating through the increasing utilization of renewable energy sources and the transition toward low-carbon economies. Electric vehicles (EVs) play a pivotal role in this transformation, contributing to the development of more flexible, sustainable, and efficient energy systems. Vehicle-to-Grid (V2G) and Grid-to-Vehicle (G2V) technologies are critical components of this process. The ability to utilize EVs both as energy consumers and as energy providers enables a more effective management of the energy supply-demand balance.

In this study, focused on the province of Batman, the contributions of EVs to demand forecasting and their impacts on the grid were evaluated. It was observed that the charging and discharging processes of EVs, particularly with the integration of V2G technology, assist in balancing energy demand. Specifically, during daytime and peak demand periods, the capability of EVs to feed energy back into the grid helps maintain the supply-demand equilibrium, thereby reducing the risk of power outages.

In the future, as the integration of EVs into energy systems becomes more widespread, significant improvements in energy systems can be achieved through the optimization of V2G and G2V technologies. With the increase in battery capacities of EVs and the development of charging infrastructures, load management on the grid can be conducted more effectively. Additionally, the incorporation of EVs into energy demand forecasting models will enable more accurate planning of power systems and ensure more efficient use of investments.

In conclusion, the critical role of EVs in managing energy supply and demand will contribute to the more efficient integration of renewable energy sources. While EVs create new opportunities within energy systems, they will also enable the development of sustainable solutions in energy management, provided that appropriate and strategic actions are taken.

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Evaluation of Wastewater Treatment Plants in the Context of the UN 2030 Sustainable Development Goals: The Case of the Batman Municipality Wastewater Treatment Plant

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A B S T R A C T

In this study, the Batman Municipality Wastewater Treatment Plant (WWTP) was evaluated within the framework of the UnitedNations 2030 Sustainable Development Goals (SDGs). The aim of the study is to examine the plant’s contributions to both thepreservation of water resources and improvements in energy efficiency. Within the context of SDG-6 (Clean Water and Sanitation) and SDG-7 (Affordable and Clean Energy), the current state of the facility was analyzed. While the physical treatment capacity allows for the safe management of water, the lack of biological and advanced treatment processes poses a barrier to the sustainability of water quality. Additionally, it has been determined that improvements are needed to enhance the plant’s energy efficiency in terms of energy consumption.

5. Introduction

As a result of industrial advancements and rapid urbanization, Wastewater Treatment Plants (WWTPs) in expanding urban areas play a vital role in protecting public health and ensuring environmental sustainability. In developing regions, the need for effective sanitation services is growing every day to improve healthcare, enhance quality of life, and support economic development. Particularly, industrial waste has become a significant global issue due to its environmental harm. Through the recovery and management of these wastes, it is thought that environmental pollution can be reduced while also contributing to the national economy [1].

Wastewater originates from domestic, industrial, and agricultural activities, and its direct discharge into streams threatens aquatic life and creates serious negative impacts on the environment [2]. Water resources are indispensable for the sustainability of life, and globally increasing population, urbanization, and industrialization are intensifying pressure on these resources. In this context, wastewater management plays a crucial role in protecting water resources, improving environmental health, and achieving sustainable development. Effective treatment and reuse of wastewater contribute to protecting the water cycle, reducing demand for clean water, and providing solutions to water scarcity. Water and energy are two resources of critical importance for modern societies, and their integrated management offers significant environmental and economic opportunities. Integrated management strategies help reduce costs by optimizing water and energy consumption while contributing to environmental sustainability by reducing greenhouse gas emissions. In this regard, energy efficiency practices in water and wastewater treatment plants have great potential for improving both economic performance and environmental impacts. Innovative technologies and approaches aimed at increasing energy efficiency play a key role in achieving the UN 2030 Sustainable Development Goals. Traditionally, water supply and energy production systems have been designed and operated independently. However, there exists an interdependent relationship between these two systems, referred to as the "Water-Energy Nexus" [3,4]. In energy production processes, large amounts of water are needed in many stages, such as cooling and steam generation; conversely, the collection, treatment, and distribution of water are energy-intensive processes. This interdependence of water and energy systems highlights the importance of integrated management strategies and coordination for the sustainable use of resources. At the same time, these interdependencies offer new opportunities for energy efficiency and water security.

The subject of this study is the evaluation of the Batman Municipality Wastewater Treatment Plant in terms of water and energy management within the context of the United Nations 2030 Sustainable Development Goals (SDGs). The aim of the study is to examine the plant’s contributions to the protection of water resources and the implementation of energy efficiency practices, and to reveal the extent to which it aligns with SDG 6 (Clean Water and Sanitation) and SDG 7 (Affordable and Clean Energy) [5-7]. In scope, the study provides a general overview of the plant’s overall sustainability performance in terms of energy efficiency and water management, rather than focusing on technical details. The limitations include that the study is conducted on a specific facility rather than a large-scale analysis and that more general conclusions are reached due to existing data limitations.

2.UN 2030 SUSTAINABLE DEVELOPMENT GOALS

In September 2015, the United Nations (UN) adopted the 2030 Agenda for Sustainable Development, which includes 17 goals (SDGs) aimed at promoting sustainable development worldwide and addressing global challenges (Figure 1). The SDGs are a continuation of the Millennium Development Goals (MDGs) and embrace a universal and inclusive approach with the motto “leaving no one behind” to ensure the well-being of all humanity. These goals provide a holistic framework aimed at balancing social, economic, and environmental sustainability.

Figure 1. UN Sustainable Development Goals

Specifically, SDG 6: Clean Water and Sanitation aims to ensure access to safe and clean water for all globally, to manage water resources sustainably, and to protect aquatic ecosystems. In parallel, SDG 7: Affordable and Clean Energy seeks to expand access to clean energy, increase the use of renewable energy, and improve energy efficiency. The strong link between water and energy demonstrates that these two goals are complementary in nature. Sustainable management of water resources not only

ensures water conservation but also enhances energy efficiency, thereby reducing greenhouse gas emissions and contributing to environmental sustainability.
The United Nations monitors and evaluates how countries address the 2030 Agenda through Voluntary National Review (VNR) Reports. Developing countries, particularly Brazil, Mexico, and Turkey, have adopted holistic approaches integrating the SDGs into their development policies. In these countries, steps are being taken to integrate sustainable development goals into national policies and strategies, strengthen institutional structures, and monitor implementation [8].

In Turkey, significant progress has been made toward achieving SDG-6 through improvements in water infrastructure and wastewater management. Projects such as SUKAP (Water, Sewerage and Infrastructure Project) aim to increase access to water and improve water management processes. The increase in the number of treatment plants and the volume of treated water between 2000 and 2016 are examples of progress in this field [8].

Under SDG-7, Turkey has made significant strides in ensuring uninterrupted access to energy. Renewable Energy Resource Area (YEKA) projects have made substantial contributions toward increasing renewable energy production and improving energy efficiency. In particular, the use of renewable energy sources has been crucial in strengthening energy supply security and reducing regional energy inequalities.

Although Turkey has made considerable progress in achieving these two goals through institutional structures and projects, further integration and monitoring processes are needed in the sustainable management of water resources and in energy efficiency. In this study, the Batman Municipality Wastewater Treatment Plant will be examined in the context of these goals, and the plant’s contributions to SDG 6 and SDG 7 will be evaluated.

3.ANALYSIS OF THE BATMAN MUNICIPALITY WASTEWATER TREATMENT PLANT

Batman province is located in the Southeastern Anatolia region of Turkey, in a basin between the Tigris River and its tributaries, the Batman and Garzan Streams. The region is situated near a major highway connecting Eastern and Southeastern Anatolia to the Middle East. Batman gained provincial status in 1990 and is situated at approximately 550 meters above sea level, with a central population of 491,811 as of 2024. The province has a continental climate; winters are cool and rainy, while summers are hot and dry. The annual average temperature is 15.9°C, with the highest temperatures occurring between June and September, and the lowest between December and March. In the city center of Batman, there is a wastewater treatment plant operated by the Batman Municipality. The Batman Municipality Wastewater Treatment Plant (WWTP) serves the urban center and has a capacity of up to 61,000 m³ per day. The plant treats wastewater using physical treatment methods only; no biological or advanced treatment processes are applied. After treatment, wastewater is discharged into the Batman Stream. The facility serves a total area of 85 km² and approximately 477,456 people. The technical specifications of the plant are provided in Table 1. Additionally, Figure 2 shows the ratio of the municipal population served by the WWTP to the total municipal population over the years [9].

Table 1. Technical Specifications of the Batman WWTP

Wastewater treatment plant	***Type of treatment plant***			***Current capacity (m^3/day)***	***Discharge point***	***Wastewater collection area (km^2)***	***Wastewater service population***
	Fiziksel	***Biyolojik***	***İleri***				
Batman	Available	NA	NA	61000	Batman River	85	477,456

Figure 2. Ratio of the Municipal Population Served by the WWTP to the Total Municipal Population by Year

Figure 2 shows the ratio of the municipal population served by the WWTP to the total municipal population between 2004 and 2023. The horizontal axis presents the years, while the vertical axis shows the percentage ratio. In 2004, this ratio started quite high at 95%, indicating that at that time, WWTP services reached a large portion of the municipal population. In the following years, the ratio gradually declined. Although the ratio seemed to stabilize around 70% in recent years, a more pronounced decline was observed in 2023. This figure demonstrates that wastewater treatment plants have started to serve a smaller proportion of the municipal population. The downward trend indicates both insufficient infrastructure capacity and the necessity of expanding services in response to population growth. Renewing the WWTP infrastructure, increasing its capacity, and extending services to more areas are critically important for sustainable environmental management and public health.

In the context of SDG-6 (Clean Water and Sanitation), the physical treatment capacity of the Batman Wastewater Treatment Plant allows for the safe management of domestic and industrial wastewater in the region. However, using only physical treatment methods is not sufficient for the long-term protection and improvement of water quality. The lack of biological and advanced treatment methods means that water is not fully cleaned and may not meet international quality standards. In a 2019 master's thesis by Baltaş [10], it was revealed that while the plant is generally effective in removing heavy metals such as arsenic, lead, cobalt, and selenium, cadmium could not be completely treated, and some metals were still present in treated effluent and clean water samples at low levels. This situation indicates the need for more advanced techniques to improve the plant's performance and treatment capacity. Furthermore, it may put pressure on aquatic ecosystems and indirectly threaten human health and biodiversity. The discharges into the Batman Stream show that more advanced treatment processes are needed to protect water quality. Integrating advanced treatment technologies would help preserve the water cycle and better align with SDG-6 targets.

Another important aspect of SDG-6 is the efficient use and reuse of water. At the Batman Wastewater Treatment Plant, the potential for reusing treated water remains limited. Water reuse offers an important solution in regions experiencing water scarcity and reduces demand for clean water. The reuse of wastewater in areas such as agricultural irrigation or industry can directly contribute to the sustainable management of water resources. The increasing risk of water scarcity, especially in the Southeastern Anatolia Region of Turkey, makes the integration of such practices into the plant even more important.

From the perspective of SDG-7 (Affordable and Clean Energy), energy efficiency does not appear to be a primary focus at the Batman Wastewater Treatment Plant in its current state. Yet, mechanical equipment and pumping processes used in wastewater treatment plants consume large amounts of energy. The plant's energy consumption data (2023-2024) are provided in Table 2. In total, the Batman Wastewater Treatment Plant consumed 949,310 kWh of electricity during this period. Notably, more energy was used during the T1 time slot, indicating higher energy use during peak working hours. Additionally, electricity consumption remained steady between periods, with significant spikes observed in some months. For example, consumption peaked at 122,520 kWh in August 2024. This consumption data demonstrates the plant's potential to optimize energy efficiency and suggests that efficiency-enhancing measures could be implemented in the T2 and T3 periods to achieve greater energy savings.

Table 2. Electricity Consumption of the Batman WWTP

Date	T1 (07:00-18:00)	T2 (18:00-23:00)	T3 (23:00-07:00)	Active kWh
31/08/2023	36,421	17,157	27,543	81,122
04/09/2023	961	84	589	1,634
30/09/2023	2,020	1,030	1,687	4,736
31/10/2023	40,843	20,806	33,678	95,328
30/11/2023	16,669	8,921	14,673	40,263
31/12/2023	50,519	26,820	40,878	118,217
31/01/2024	13,921	6,991	11,389	32,300
29/02/2024	38,576	19,433	30,555	88,564
31/03/2024	46,638	23,979	38,502	109,119
30/04/2024	21,278	10,169	17,017	48,465
31/05/2024	42,245	20,399	33,446	96,091
30/06/2024	33,475	15,521	25,336	74,332
31/07/2024	16,276	7,669	12,675	36,619
31/08/2024	55,593	25,685	41,242	122,520
TOTAL	**415,435**	**204,664**	**329,210**	**949,310**

In the first six months of 2018, the sludge at the plant produced a total of 497,369 m³ of methane gas through bacteria in the sludge digester tank, and the methane produced was used for heating and electricity needs. Reducing the plant's energy consumption and integrating renewable energy sources can provide significant benefits in terms of both environmental sustainability and operational costs. In particular, the integration of renewable energy technologies such as biogas production into treatment processes would allow energy recovery from organic matter released during wastewater treatment. Biogas is generated through the anaerobic digestion of sludge produced during the treatment process, and this energy can be used to meet the plant's own energy needs or excess energy can be sold externally. Such innovative practices are an important step toward achieving SDG-7 targets. Additionally, energy efficiency audits should be conducted to optimize the plant's energy consumption, and low-energy-consuming equipment such as efficient pumps and motors should be used. The integration of smart energy management systems could further increase energy efficiency by monitoring the plant's energy consumption in real time. Such practices would reduce the operational costs of the Batman Wastewater Treatment Plant while also lowering its carbon footprint.

4. CONCLUSION AND RECOMMENDATIONS

The current state of the Batman Municipality Wastewater Treatment Plant reveals areas in need of improvement in both water management and energy efficiency within the framework of the United Nations 2030 Sustainable Development Goals (SDGs). The findings of the study highlight specific shortcomings that must be addressed to fully achieve SDG-6 and SDG-7 targets. In conclusion, the following points should be considered:

• The plant employs only physical treatment methods, which limits the long-term protection of water

quality.
• The integration of biological and advanced treatment technologies is necessary to improve water quality.
• Supporting discharges into the Batman Stream with advanced treatment processes would contribute to the protection of aquatic ecosystems and the improvement of public health.
• The plant consumed a total of 949,310 kWh of electricity in 2023-2024.
• Peak consumption occurs during the T1 time slot (07:00-18:00), with a peak of 122,520 kWh in August 2024.
• Energy efficiency should be improved, and consumption during peak hours should be optimized.
• Renewable energy sources, particularly processes such as biogas production, should be integrated.
• In 2018, 497,369 m^3 of methane production partially met energy needs; further development of these processes could increase energy efficiency.

In conclusion, modernizing the plant's water and energy management processes would make a significant contribution to achieving both SDG-6 and SDG-7 targets. In this context, the following recommendations are made:

• The integration of biological and advanced treatment technologies is necessary to preserve and improve water quality and is critical for the sustainability of aquatic ecosystems.
• To improve energy efficiency, smart energy management systems and more efficient equipment should be utilized, and renewable energy sources such as biogas production should be made more effective.
• Integrating water reuse and recycling strategies into the plant's infrastructure would provide an important solution against the risk of water scarcity.

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