**ISSN 1840-4855**
**e-ISSN 2233-0046**

**Review Article**
**http://dx.doi.org/10.70102/afts.2025.1833.637**

# HISTORICAL PERSPECTIVES ON RENEWABLE ENERGY ADVANCEMENTS AND THEIR ROLE IN SHAPING GLOBAL ENERGY EFFICIENCY STRATEGIES

Nargiza Jabborova[1], Nozimjon Ibrokhimov[2], Feruza Kilicheva[3], Sabohat Alimova[4], Sevara Begmatova[5], Gulshan Aliyeva[6], Abdulaziz Mattiyev[7]

*[1]Termez University of Economics and Service, Termez, Uzbekistan.*
*e-mail: nargiza_jabborova@tues.uz, orcid: https://orcid.org/0009-0001-7274-0775*
*[2]Department of Social Sciences, Bukhara State Pedagogical Institute, Bukhara, Uzbekistan. e-mail: nozimjonibrohimov086@gmail.com,*
*orcid: https://orcid.org/0009-0006-9410-2180*
*[3]Department of Education, Renaissance Educational University, Tashkent, Uzbekistan.*
*e-mail: kilichevaferuza1967@gmail.com, orcid: https://orcid.org/0009-0002-3800-2258*
*[4]Associate Professor, Department of Social Sciences, Tashkent State Medical University (TSMU), Uzbekistan. e-mail: saboxat.alimova@mail.ru,*
*orcid: https://orcid.org/0009-0006-9410-2180*
*[5]Department of Pedagogy, University of Information Technologies and Management, Karshi, Uzbekistan. e-mail: sevara.begmatova.1990@gmail.com,*
*orcid: https://orcid.org/0009-0007-1734-0502*
*[6]Department of Filology, Jizzakh State Pedagogical University, Jizzakh, Uzbekistan.*
*e-mail: aliyevagulshan908@gmail.com, orcid: https://orcid.org/0009-0002-3189-9605*
*[7]Associate Professor, Andijan State Institute of Foreign Languages, Andijan, Uzbekistan.*
*e-mail:mattiyev1@gmail.com, orcid: https://orcid.org/0009-0002-2032-5526*

***Received: August 05, 2025; Revised: September 25, 2025; Accepted: November 07, 2025; Published: December 20, 2025***

## SUMMARY

Renewable energy technologies have existed since the earliest days of energy conservation and preservation, which have been critical to the development of modern energy conservation plans around the globe. Although the earliest applications of wind, water, and solar power date back to the second millennium, the development of renewable energy has transformed into the present, with centuries of invention and adaptation of various types of wind turbines, photovoltaic cells, and bioenergy. This paper will record the history of renewable energy technologies, including critical milestones, technological advances, and the socio-political pressures that have driven their uptake. Moreover, it examines how these developments have helped the world work towards energy efficiency and the minimization of carbon emissions. The potential of renewable energy for the development of sustainable energy systems is argued, with particular focus on its role in meeting the global climate agenda, addressing energy source variability, and enhancing energy security. Based on the different metric analyses, solar energy has an adoption rate of 30%, an LCOE of 7%, and an Annual Energy production of 100%. Wind energy possesses an adoption rate of 25%, an LCOE of 4% and an Annual 75%. The hydropower adoption rate is 20%, the LCOE is 5%, and the annual energy production is 80%. The adoption rate, LCOE, and Annual Energy output of biomass are 10%, 8%, and 50%, respectively. With the historical background and technological transformation of renewable energy, we can examine its current position and prospects for developing an energy-efficiency policy in a sustainable, low-carbon global economy.

Key words: *renewable energy, historical development, technological advancement, sustainability, wind power, solar energy, climate change, renewable technologies.*

INTRODUCTION

The transition to renewable energy is among the most critical challenges and opportunities in meeting global energy needs while simultaneously addressing climate change (Akpan & Olanrewaju, 2023; Chang et al., 2017). The use of fossil energy in the world has historically characterized the world's energy, but the growing environmental concerns, the dwindling resources, and the need to have sustainable development have changed these priorities to rely on renewable sources of energy (Androniceanu et al., 2024). Wind, solar, hydro, and bioenergy have long been used as energy sources; only over the past few decades have renewable sources become a feasible and scalable option to address global energy consumption (Alattabi et al., 2025). Renewable energy has played a role in developing energy efficiency strategies to address the increased need for cleaner, more reliable, and affordable energy. Besides reducing dependence on non-renewable resources, renewable technologies have also contributed to the emergence of integrated systems designed to enhance energy efficiency across industries, transport, and residential markets (Hasenöhrl & Meyer, 2020; Gajdzik et al., 2024). During this time, as historical changes occurred, early watermills and windmills gave way to contemporary solar panels and wind turbines, which taught people a lot about innovation, scalability, and the technological orientation of technology to policy and market incentives (Saeed & Siraj, 2024; Dragomir & Kovacs, 2022). The purpose of this paper is to examine the historical outlook on renewable energy progressions and how they have changed the world's energy efficiency policy. In light of the development of renewable energy technologies and their impact on sustainable energy systems, this piece of work seeks to shed light on how the past shapes the present and future of energy efficiency worldwide. It also refers to the far-reaching consequences of such developments for energy security, environmental sustainability, and the international resolve to reduce carbon emissions in the wake of global warming.

**Key Contribution**

- Additional research is required to improve how intermittent renewable sources such as wind and solar are integrated into current power grids, to maintain grid stability and reliability.
- Although technology costs are decreasing, significant initial investments and infrastructure challenges persist. Further research should focus on developing new financing mechanisms and market frameworks to lower costs and enhance accessibility and competitiveness.
- Ongoing progress in energy storage technologies is essential for providing cost-efficient, scalable, and environmentally friendly ways to store and utilize renewable energy.

The following sections cover this report. Section I introduces the research topic, followed by a Historical perspective on renewable energy advancements and their role in global energy efficiency strategies. Section II discusses related work and defines the research gap. Section III describes the research methodology, which falls under the overall diagram, the data flow diagram, and the proposed algorithm. Section IV describes the results and discussion, which falls under the dataset description, Hardware materials, and parameters, and also includes the evaluation metric analysis. Section V presents the research's key findings and concludes the study.

LITERATURE REVIEW

The evolution of renewable energy sources has undergone drastic changes over the last few centuries, and ancient human civilizations used the natural resources of wind, water, and sunlight to power their societies. In the early days, renewable sources were used only for mechanical purposes, e.g., windmills for grain grinding or watermills for pumping water (Saygin et al., 2015; Idoko et al., 2024). Technological progress over time has enabled more intricate applications, such as using wind power to generate electricity and solar energy to heat and generate electricity (Jandaghi & Rashidi, 2014). The last century of the 20th century was a turning point in the development of renewable energy technologies, influenced by industrialization and the growing awareness of the environmental and economic issues of fossil fuel dependence (Chakraborty, 2011; Raihan, 2023). Innovation and research resulted in the invention of more efficient solar photovoltaic cells, wind turbines, and bioenergy systems. There was also a rising trend of political and economic support in the field of renewable energy due to these technological improvements as governments started to consider the vitality of energy diversification and security (Rajalakshmi et al., 2024; Singh & Singh, 2024). Over the past few decades, the focus on renewable energy has shifted to its contribution to the further development of global energy efficiency strategies. The increased awareness of the environmental impacts of conventional energy sources, such as air pollution and climate change, has contributed to efforts to enhance energy efficiency across all sectors (Nwokediegwu et al., 2024). Renewable energy technologies are viewed as major facilitators of these strategies, offering cleaner alternatives to traditional energy sources and aiding the development of low-carbon energy systems (Lal et al., 2025). Solar and wind energy, among others, have become even more competitive than fossil fuels not only in environmental terms but also in cost efficiency. One of the challenges has been the storage and management of renewable energy, since sources such as wind and solar are intermittent (Alotaibi et al., 2020). Nevertheless, advances in battery technology and grid management have enabled more reliable, adaptable energy systems, making it easier to integrate renewable sources into the global energy system. This has led to significant improvements in overall energy efficiency, as renewable energy is now more easily accessible and has been integrated into the existing energy infrastructure (Suprihartini et al., 2023). International efforts to set sustainable development targets and reduce the effects of climate change have further increased the use of renewable energy technologies (Adeyinka et al., 2024). The need to reduce carbon emissions and the encouragement of renewable energy have been given higher priority in international agreements and national policies aimed at achieving these objectives. Consequently, renewable energy has been put at the center of energy efficiency policies around the world, not only to minimize the environmental impact of energy production, but also to drive the overall shift toward sustainable and resilient energy systems. Besides technological innovations, one cannot overlook the social, political, and economic factors that have shaped the evolution of renewable energy (Ekechukwu & Simpa, 2024). Renewable energy has been widely adopted through a combination of public awareness, policy incentives, and international collaborations. With renewable energy technologies still developing, their role in advancing global energy efficiency efforts will always be central to the quest for a sustainable, low-carbon world.

**Research Gap**

Renewable energy technologies have become significantly more advanced; several research gaps remain that prevent their full realization. These involve better integration of intermittent renewable energy sources such as wind and solar into existing grid systems, with particular focus on grid flexibility and reliability. More innovation in energy storage technology is essential to deliver more effective, affordable, and sustainable solutions for renewable energy storage. More studies are also required on cost-cutting in renewable energy, new economic models, and improvements in policymaking to hasten technology implementation, especially in developing countries. Although renewable energy has been regarded as a clean energy source, there has been little research on its life-cycle implications, including the extraction and disposal of materials. More attention should also be paid to social and behavioral factors and to public acceptance, which would help it be adopted most widely. Moreover, the long-term sustainability, resilience to climate change, and the mainstreaming of renewable energy across many spheres and areas should be further explored to ensure a strong and fair energy transition. It is crucial to address these gaps so that renewable energy technologies can make greater contributions to the development of global energy efficiency strategies and the realization of sustainability objectives.

RESEARCH METHODOLOGY

### 3.1 Overall Architecture Diagram

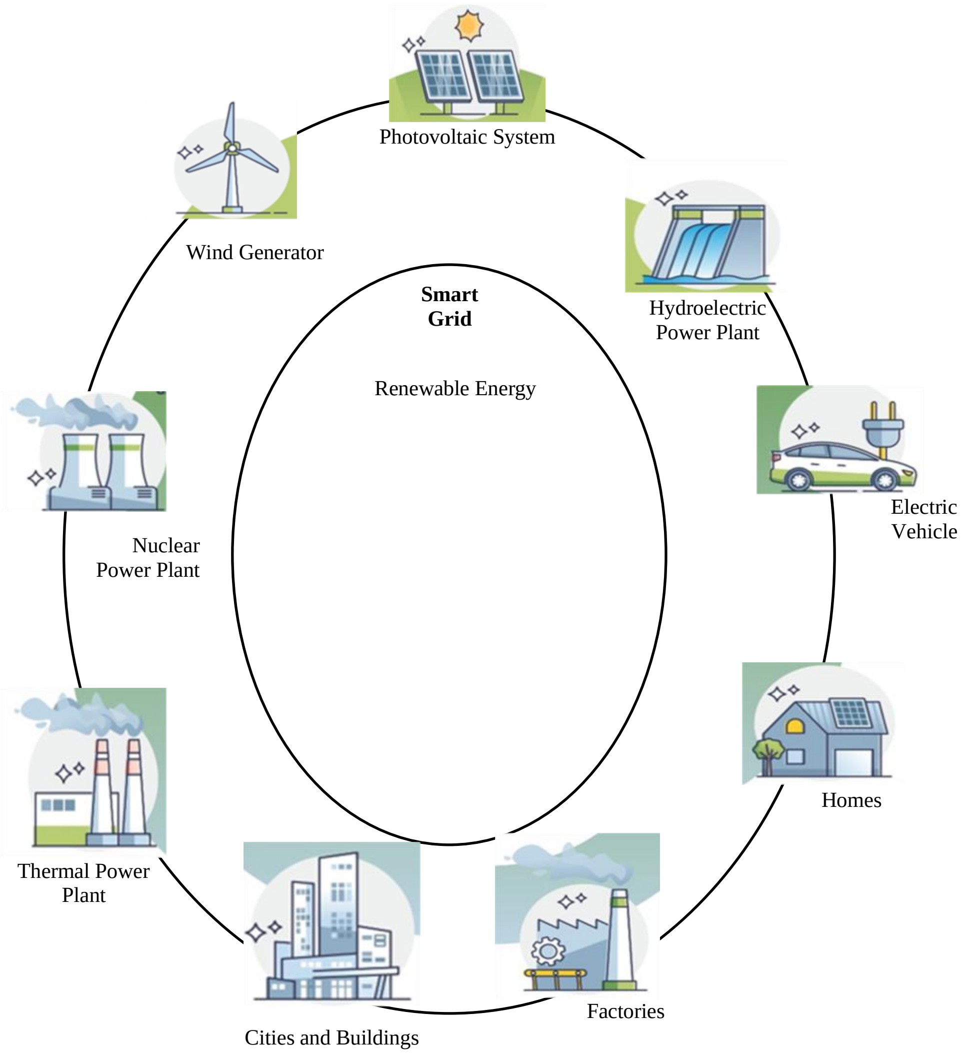


Figure 1. Overall architecture diagram smart grid system

In figure 1, the diagram is a broad representation of an intelligent grid system, with the integration of renewable energy and conventional power generation methods highlighted. Renewable energy sources such as wind power generators, photovoltaic systems (solar energy), and hydroelectric power plants are depicted at the top, which are clean sources of energy for the grid. These sources are linked to each other via the central smart grid, which serves as the basis for effective energy control and distribution. Conversely, traditional energy-generating processes, such as nuclear and thermal power plants, are also linked to the grid, underscoring the integration of renewable and conventional energy. The diagram also identifies the final consumers of this energy: homes, electric cars, factories, and cities. This networked system shows how the smart grid will help with energy distribution across various fields, enabling the use of renewable power more effectively without loss at times. The graphical illustration depicts the reciprocal relationship between renewable and non-renewable energy generation, consumption, and storage in a smart grid, reflecting the contribution of this factor to modernizing energy management.

#### *3.1.1 Smart Grid System*

The mathematical representation of a Smart grid system that incorporates Renewable Sources, a Conventional Power Plant, and Customer Demand comprises Production, Distribution, Storage, and Demand-side Management. The following is a basic mathematical formula that describes some of these components.

*3.1.2 Energy Generation*

In an intelligent grid system, electricity from renewable and non-renewable sources is efficiently combined to serve consumer needs while ensuring grid stability. Green energies such as solar, wind, and hydroelectric power are also adding to the power grid by providing renewable energy that is sustainable and does not cause environmental degradation. The non-renewable ones, like thermal and nuclear power stations, offer a predictable, regulated amount of energy, particularly during periods when renewable energy is insufficient. Energy storage systems, such as batteries, are essential for balancing the intermittency of renewable energy. The smart grid uses new technologies such as sensors and communication systems to streamline energy production and delivery, making it more reliable and efficient. Smart grids enable a flexible, resilient energy system by combining decentralized generation, real-time monitoring, and demand-side management, helping minimize waste, maximize sustainability, and respond to shifting demand.

$$P_{gen} = P_{renewable} + P_{traditional} \tag{1}$$

Equation (1) describes the above. $P_{gen}$ as a combination of non-renewable resources, $P_{renewable}$ Consider the power generated by various energy sources, such as wind, solar, and hydroelectric. $P_{traditional}$ As the power generated by non-renewable resources is thermal and nuclear, power plants are considered non-renewable.

*3.1.3 Energy Storage and Distribution*

Energy storage and distribution is the process of capturing surplus electricity produced during low-demand times and storing it for later use when demand may be low, thus providing a reliable and consistent power supply. Battery, pumped hydro, compressed air, and thermal storage are all types of energy storage technologies used to stabilize the intermittency inherent in renewable energy sources such as wind and solar. When stored, electricity is supplied to consumers via transmission and distribution lines, substations, and transformers. This distribution is optimized in a smart grid through real-time monitoring, sensors, and communication technologies to dynamically adjust demand and supply and ensure efficient, reliable energy delivery. Energy storage and distribution together promote grid stability and mobility, supporting both renewable and non-renewable sources of energy.

$$E_{storage}(t) = C_{storgae} * SOC\ (t) \tag{2}$$

From the above Equation (2) describes about $E_{storage}(t)$ consider as the energy stored at the time of t. SOC (t) is considered as the charge of the battery at time t.

$$P_{dist}\ (t) = P_{gen}(t) - P_{demand}(t) + \Delta E_{storage}\ (t) \tag{3}$$

Equation (3) describes $P_{dist}\ (t)$ consider as the power distributed at the time of t.$P_{demand}(t)$ describes the power demand from the end users. $\Delta E_{storage}\ (t)$ Noted as the change in storage.

### 3.2 Dataflow Diagram of Renewable Energy Advancements and Their Role in Shaping Global Energy Efficiency Strategies

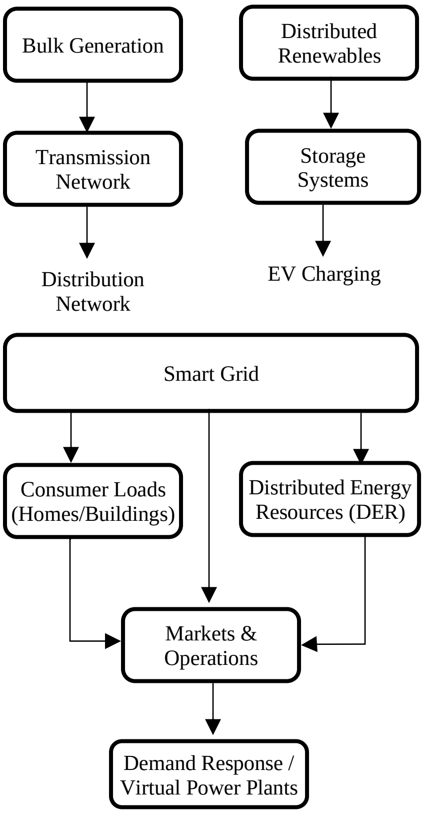


Figure 2. Data flow diagram of smart grid system

The diagram figure 2 presents the major elements and processes of a smart grid system, where both bulk generation and small-scale renewable energy sources have been integrated. On the left, there is bulk generation (e.g., large-scale thermal or nuclear plants) and distributed renewables (e.g., rooftop solar panels or small wind turbines), which supply electricity to the system. The energy is further carried through the transmission network to the distribution network, which is taken nearer to end users. In addition, storage systems and EV charging stations play a crucial role in balancing supply and demand, storing excess energy for later use and charging electric vehicles, respectively. These components are centralized in the smart grid, which oversees the determination of electricity flow to consumer loads (homes and buildings) and the integration of distributed energy resources (DER), including home-based solar panels or small energy storage devices. Markets and operations control the system and include demand response and virtual power plants, which optimize energy consumption and distribution in real time. In this way, traditional and renewable energy will be consumed efficiently, increasing the reliability, flexibility, and sustainability of the grid.

### 3.3 Algorithm for Smart Grid Energy Management System

Initialize Components
define Generation, distributed renewables, EV charging, stoarge systems
minitor energy generation
check power from renewablesources wind, solar and hydro
update total energy generation
energy storage
if energy generation > demand

if energy generation < demand
EV charging Management
Energy Distribution
DemandResponses
Real time Monitoring
Grid Stability & Fault Detection
generate Reports − Grid performance, energy use and demand response actions
monitoring and managing the energy generation

RESULTS AND DISCUSSION

### 4.1 Dataset Description

This dataset provides a comprehensive overview of new renewable energy technologies and their role in the adoption of global energy efficiency strategies. Data are presented for each of the individual sources of energy production: solar, wind, and hydro; it identifies all industrialized nations and tracks their investments and policies related to renewables. The dataset is intended to provide a basis for understanding which investments will be most beneficial for achieving the most tremendous improvements in renewable energy technology and policy, as well as for reducing the carbon footprint associated with energy use worldwide.

### 4.2 Hardware Materials and Parameters

Table 1. Hardware materials and parameters

| Category | Materials | Parameters |
|---|---|---|
| Energy Generation | - Solar Panels: Silicon, glass, conductive materials | Efficiency (%) |
| Energy Storage | - Batteries: Lithium-ion, lead-acid, nickel-cadmium, lithium iron phosphate (LiFePO4) | - Storage Capacity, Efficiency, Cycle Life |
| Grid Infrastructure | - Smart Meters: Plastic, glass, electronics, wireless communication modules | - Voltage Range, Current Rating, Data Transmission Rate |
| Smart Grid Communication | - Communication Networks: Fiber optics, wireless networks, power-line communication systems | - Bandwidth, Latency, Data Transmission Range |
| Consumer Hardware | - Home Energy Storage Systems: Lithium-ion batteries, inverters, energy controllers | - Storage Capacity (kWh), Efficiency (%), Power Output (kW) |
| Backup Power Systems | - Generators: Diesel, natural gas, steel, copper, control systems | - Power Rating (kW), Fuel Type, Efficiency (%), Runtime (hrs) |

The hardware elements and their respective specifications are presented in Table 1 for electric generation, energy storage, and intelligent grid systems. In electric generation, several types of materials are used in the manufacture of solar photovoltaic (PV) modules. The principal materials used for this type of system include silicone, glass, and conductive materials, and solar PV modules are evaluated based on their ability to convert sunlight into electrical energy (i.e., conversion efficiency). Storage systems use various types of batteries, such as lithium-ion, lead-acid, nickel-cadmium, and lithium iron phosphate (LiFePO4), each with specific requirements, including storage capacity (kWh), power conversion efficiency (%), and cycle life (cycles). The cycle life (accuracy and longevity) of a battery determines how long it will last and how effectively it stores energy over time. The Smart Grid infrastructure relies heavily on Smart Meters made from various materials, including plastic, glass, and electronic components. Smart Meters are evaluated based on various specifications, including voltage rating (V), current rating (A), and data transmission rate (bps), to ensure accurate measurement and communication of energy usage. The communication portion of the smart grid relies on fiber-optic and wireless networks, and the bandwidth, latency, and transmission distance of these networks must also be considered to achieve real-time data transfer for grid operations. Consumer hardware for home energy storage systems (lithium-ion batteries), inverters, and energy controllers must be evaluated based on storage capacity (kWh), power conversion efficiency (%), and total power output (kW) for efficient home energy management.

### 4.3 Evaluation Metric Analysis

A clear set of measurements has been established against which to evaluate how well renewable energy has developed and how well it has promoted energy efficiency worldwide. These measurements will enable you to assess your level of improvement, your level of impact, and how well (or poorly) renewable energy technology performs against others. The development of renewable energy technologies is a key component of the approach to achieving sustainable development globally. The following section will analyze current trends and historical records to develop an evaluative tool for measuring the performance of renewable energy technologies relative to other energy efficiency technologies.

*4.3.1 Renewable Energy Adoption Rate*

This metric measures the annual growth rate of renewable energy sources, as shown in Equation (4), expressed as a percentage of total energy consumption or generation worldwide or within specific regions.

$$Adoption\ Rate = \frac{Renewable\ Energy\ Generation}{Total\ Energy\ Generation} * 100 \tag{4}$$

*4.3.2 Cost of Renewable Energy Technologies*

Equation (5) calculates the capital cost or levelized cost of electricity (LCOE) for renewable energy technologies such as solar, wind, and hydropower etc.).

$$LCOE = \frac{Total\ Lifetime\ Cost\ of\ Plant}{Total\ Lifetime\ Energy\ Output} \tag{5}$$

*4.3.3 Adoption Rate and LCOE for Smart Grid System*

Table 2. Adoption rate and LCOE for smart grid system

| **Model** | **Solar Energy** | **Wind Energy** | **Hydro Power** | **Biomass** | **Geothermal** |
|---|---|---|---|---|---|
| Adoption Rate | 30% | 25% | 20% | 10% | 5% |
| LCOE | 7% | 4% | 5% | 8% | 10% |
| Annual Energy Output | 100% | 75% | 80% | 50% | 30% |

The adoption rates and LCOE for smart grid systems in Table 2 and Figure 3 show that there are four different renewable energy sources being evaluated (Geothermal, Biomass, Hydro Power, Wind Energy, and Solar Energy) using three different measuring sticks or metrics: Annual Energy Output, Levelized Cost of Energy (LCOE), and Adoption Rate. Of these, Solar Energy produces the most energy output, and Geothermal Energy follows closely behind. The next two are Wind Energy and Hydro Power, while Biomass produced the least. The LCOE metric shows Geothermal Energy has the lowest cost to produce (LCOE), making it the most economically efficient per unit of energy. The next lowest is Hydro Power, followed by the two mid-range costs of Wind Energy and Solar Energy, respectively, with Biomass being the highest (most expensive) of the four. The adoption rate metric shows Solar Energy has the highest adoption over other options meaning it has been accepted and used by many. Geothermal has the next highest but not as much as solar energy.

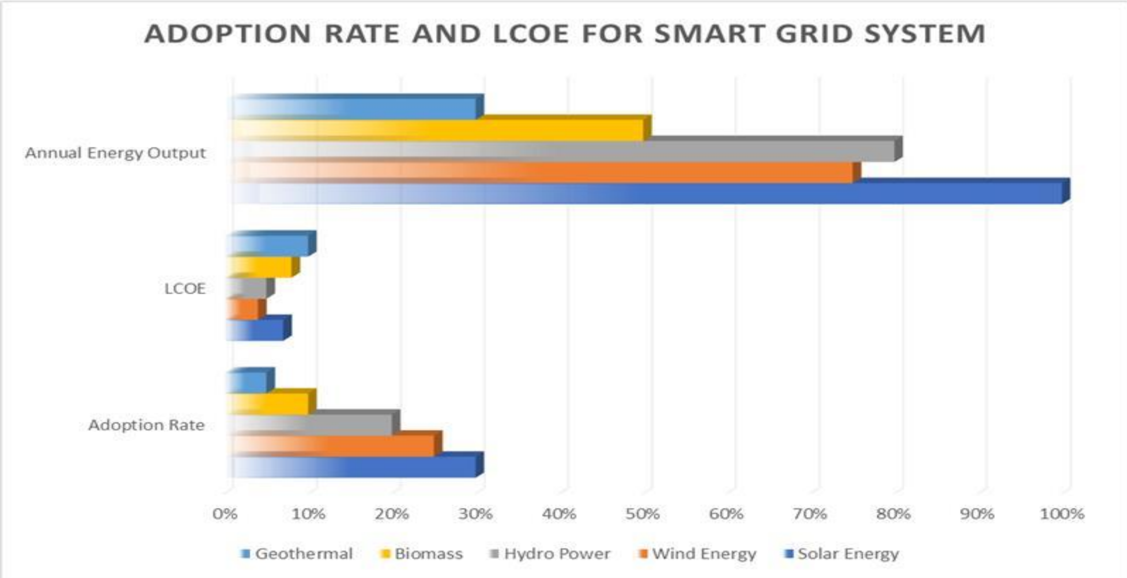


Figure 3. Adoption rate and LCOE for smart grid system

## CONCLUSION

The evolution of renewable energy technologies was integral to developing current energy efficiency techniques and addressing worldwide climate change issues. The advancement of renewable energy was an evolution of past renewable uses such as wind power (via sails), hydropower (via water turbines), and solar power through modern added technologies such as improved efficiency rate electronic wind turbines, high-efficiency photovoltaic cells (through use of silicon), biofuels to produce heat and electricity. Technological advancements, along with social-political driving forces, have created a need for renewable energy to help achieve global climate change goals, provide a diversified energy supply, and guarantee energy security. The data collected from the research of all types of renewable energy currently indicates that solar energy will be widely used throughout the world (30%); the Levelized cost of electricity (LCOE) on solar is 7% and the Levelised cost of electricity (LCOE) based on total annual solar energy output is equal to 100%. The research shows that wind energy ranks second among renewable energy sources (25% adoption rate), has the lowest Levelized cost of electricity (LCOE) (4%), and has the highest total annual wind energy output (75%). Hydropower accounts for 20% of the total renewable energy utilized worldwide, has a Levelized cost of electricity (LCOE) of 5%, and accounts for 80% of total annual hydropower energy output. Biomass has the lowest percentage of renewable energy adoption worldwide (10%), the highest Levelised cost of electricity (LCOE) (8%), and the lowest biomass annual energy output (50%). The data demonstrate that although solar energy is currently the most widely adopted renewable energy source and has the highest total energy output, wind and hydro are also low-cost, reliable energy sources. Biomass continues to serve as a variable in helping to maintain a diverse energy mix, although it has both a high cost and low adoption rate. To maximize the effectiveness of solar and wind energy, continued innovation in energy storage and grid connectivity, and the scale-up of all forms of renewable energy technology over the next few years will be essential. In the Future, reductions in LCOE for renewables driven by advances in biomass will improve their ability to compete with more traditional sources of electricity. Policy initiatives that foster infrastructure development and incentivize renewable energy growth will help advance the transition to renewable energy sources. Understanding the historical and technological context of renewable energy sources, as well as their future potential, will allow us to better appreciate the current role and long-term benefits of renewable resources in providing a sustainable, low-carbon global economy, with regard to environmental, economic, and energy security.

## REFERENCES

[1] Akpan J, Olanrewaju O. Sustainable energy development: History and recent advances. Energies. 2023 Oct 11;16(20):7049. https://doi.org/10.3390/en16207049

[2] Chang RD, Zuo J, Zhao ZY, Zillante G, Gan XL, Soebarto V. Evolving theories of sustainability and firms: History, future directions and implications for renewable energy research. Renewable and sustainable energy reviews. 2017 May 1;72:48-56. https://doi.org/10.1016/j.rser.2017.01.029

[3] Androniceanu A, Veith C, Ionescu ȘA, Marinescu P, Sima AG, Paru A. Shaping sustainable futures: public policies and renewable energy insights based on global bibliometric analysis. Sustainability. 2024 Jun 10;16(12):4957. https://doi.org/10.3390/su16124957

[4] Alattabi IA, Almudhafar SM, Jafar I, Al-Naffakh J, Almayahi BA. Environmental and geo-life assessment to produce alternative fuel from plastic waste and used motor oil: A sustainable energy approach for Iraq. Int J Aquat Res Environ Stud. 2025;5(1):95-109. https://doi.org/10.70102/IJARES/V5S1/5-S1-11

[5] Hasenöhrl U, Meyer JH. The energy challenge in historical perspective. Technology and Culture. 2020;61(1):295-306. https://doi.org/10.1353/tech.2020.0003

[6] Gajdzik B, Wolniak R, Nagaj R, Žuromskaitė-Nagaj B, Grebski WW. The influence of the global energy crisis on energy efficiency: A comprehensive analysis. Energies. 2024 Feb 18;17(4):947. https://doi.org/10.3390/en17040947

[7] Saeed S, Siraj T. Global Renewable Energy Infrastructure:: Pathways to Carbon Neutrality and Sustainability. Solar Energy and Sustainable Development Journal. 2024 Aug 31;13(2):183-203.

[8] Dragomir AM, Kovacs A. Waste-to-energy technologies: Converting industrial waste into usable energy. International Academic Journal of Innovative Research, 9(3), 2022;9(3):25-30. https://doi.org/10.71086/IAJIR/V9I3/IAJIR0922

[9] Saygin D, Kempener R, Wagner N, Ayuso M, Gielen D. The implications for renewable energy innovation of doubling the share of renewables in the global energy mix between 2010 and 2030. Energies. 2015 Jun 17;8(6):5828-65. https://doi.org/10.3390/en8065828

[10] Idoko IP, Ijiga OM, Harry KD, Ezebuka CC, Ukatu IE, Peace AE. Renewable energy policies: A comparative analysis of Nigeria and the USA. World Journal of Advanced Research and Reviews. 2024;21(1):888-913. https://doi.org/10.30574/wjarr.2024.21.1.0071

[11] Jandaghi SB, Rashidi S. Survey based building design renewable energy affected by passive solar systems. International Academic Journal of Science and Engineering, 2014;1(2):106-116.

[12] Chakraborty A. Advancements in power electronics and drives in interface with growing renewable energy resources. Renewable and Sustainable Energy Reviews. 2011 May 1;15(4):1816-27. https://doi.org/10.1016/j.rser.2010.12.005

[13] Raihan A. An overview of the energy segment of Indonesia: present situation, prospects, and forthcoming advancements in renewable energy technology. Journal of Technology Innovations and Energy. 2023 Sep 19;2(3):37-63. https://doi.org/10.56556/jtie.v2i3.599

[14] Rajalakshmi AR, Jayakani S, Shanmugam H, Ramakrishnan PR. Green Products and Electronic Word of Mouth: A Study Special Reference with Significance of Environmental Concern, Knowledge and Consciousness. Indian Journal of Information Sources and Services. 2024;14(4):79-85. https://doi.org/10.51983/ijiss-2024.14.4.13

[15] Singh S, Singh S. Advancements and challenges in integrating renewable energy sources into distribution grid systems: A comprehensive review. Journal of Energy Resources Technology. 2024 Sep 1;146(9):090801. https://doi.org/10.1115/1.4065503

[16] Nwokediegwu ZQ, Ibekwe KI, Ilojianya VI, Etukudoh EA, Ayorinde OB. Renewable energy technologies in engineering: A review of current developments and future prospects. Engineering science & technology journal. 2024 Feb;5(2):367-84. https://doi.org/10.51594/estj/v

[17] Lal SR S, Herbert GM J, Arjunan P, Suryan A. Advancements in renewable energy transition in India: A review. Energy sources, part A: recovery, utilization, and environmental effects. 2025 Dec 12;47(2):2024921. https://doi.org/10.1080/15567036.2021.2024921

[18] Alotaibi I, Abido MA, Khalid M, Savkin AV. A comprehensive review of recent advances in smart grids: A sustainable future with renewable energy resources. Energies. 2020 Nov 27;13(23):6269. https://doi.org/10.3390/en13236269

[19] Suprihartini Y, Taryana, Andiyan, Cakranegara PA, Dwiyandana D. Utilization of motion sensors to reduce electricity consumption in buildings. Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 2023;14(2):94-108. https://doi.org/10.58346/JOWUA.2023.I2.008

[20] Adeyinka AM, Esan OC, Ijaola AO, Farayibi PK. Advancements in hybrid energy storage systems for enhancing renewable energy-to-grid integration. Sustainable Energy Research. 2024 Jul 20;11(1):26.

[21] Ekechukwu DE, Simpa P. The intersection of renewable energy and environmental health: Advancements in sustainable solutions. International Journal of Applied Research in Social Sciences. 2024;6(6):1103-32. https://doi.org/10.51594/ijarss.v6i6.1175