ISSN No:-2456-2165

Analyzing Market Trends in Energy Efficiency: Opportunities and Challenges in the U.S. Sector

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Abstract:- Energy efficiency has become a cornerstone of sustainable development, addressing both historical energy crises and modern environmental challenges. Energy efficiency has emerged as a critical component in addressing climate change and promoting sustainability, particularly in the United States. This paper provides a comprehensive survey of the evolution, challenges, and opportunities within the U.S. energy efficiency market. The historical context from the 1970s oil crises to present-day advancements is discussed, with an emphasis on barriers such as high upfront costs, fragmented opportunities, and low consumer awareness. Key trends in technology development, regulatory measures, and market growth, particularly in the building and industrial sectors, are examined. The role of smart grids, energy management systems, and IoT technologies in driving energy efficiency is also highlighted. Through the analysis of case studies, including the use of Power BI for energy consumption tracking, the paper underscores the potential for technological innovations and policy frameworks to accelerate the adoption of energy-efficient practices across diverse sectors. The study concludes by proposing strategic recommendations for overcoming existing barriers and unlocking the full potential of energy efficiency in mitigating climate change and fostering sustainable development.

Keywords:- *Energy Efficiency, Market Trends, U.S. Sector, Challenges, Smart Technologies, Market Analysis, Industrial Sector.*

I. INTRODUCTION

The global shift towards energy efficiency has become an essential component of sustainable development, driven by the urgent need to address energy scarcity, climate change, and environmental degradation. As fossil fuel reserves deplete and the adverse impacts of greenhouse gas emissions become increasingly evident, energy efficiency has risen to the forefront of policy agendas, particularly in sectors with high energy consumption such as manufacturing, transportation, and buildings [1]. This global focus on energy conservation aims not only to reduce consumption but also to optimize energy usage, improve competitiveness, and mitigate environmental harm[2].

In the U.S., the drive towards energy efficiency has been shaped by both regulatory frameworks and market dynamics, responding to the growing demand for sustainable energy solutions[3]. The U.S. energy efficiency market has expanded significantly over the past few decades, as advancements in technology, evolving consumer behaviors, and government policies converge to create new opportunities. However, challenges persist, particularly in terms of ensuring that energy efficiency programs effectively reach all sectors of society, including low-income households and industries heavily dependent on energy[4]. Despite the progress, a critical gap remains in fully integrating energy efficiency strategies into everyday practices and aligning them with broader sustainability goals[5].

Technology solutions are central to overcoming these barriers, providing innovative tools that enable both consumers and industries to reduce energy consumption while maintaining economic viability[6]. In particular, the rise of smart technologies, such as smart meters, demand response systems, and energy management platforms, is transforming the way energy is monitored and utilized[7]. These technologies offer the potential to enhance efficiency by providing real-time data[8][9], enabling more informed decision-making, and supporting the integration of renewable energy sources into the grid. As the U.S. continues to grapple with its energy challenges, the combination of policy incentives, technological [10]advancements, and market-driven solutions will play a crucial role in shaping the future of energy efficiency[11].

- *Structure of this Paper*

The structure of paper: **Section II** providing an overview of the significance of energy efficiency and its impact on various sectors**. Section III** explores Market Trends in Energy Efficiency, focusing on the growth of the energy-efficiency services market. **Section IV** delves into the US Energy Efficiency Movement's historical development, discussing the obstacles unique to the American setting for implementing energy efficiency measures. **Section V** offers Literature Review is presented to contextualize the study within existing research. Finally, **section VI** concludes with a Conclusion and Future Work.

ISSN No:-2456-2165

II. EVOLUTION OF ENERGY EFFICIENCY IN THE UNITED STATES

In addition to significant climate change mitigation potential, energy efficiency has several major co-benefits, including improved comfort, higher productivity, less reliance on foreign energy sources, and conservation of resources [12]. Within the larger concept of energy service—"those functions performed using energy which is meant to obtain or facilitate desired end services or states"—energy efficiency is considered a subset. Produced by technology with many uses, energy services are essential to almost every sector of the economy [13][14]. In this model, energy efficiency is a technology's capacity to reduce the amount of energy input required to provide a certain amount of energy service.

- *The Classical Age (1860s-mid-20th Century)*

The most common timeline for the beginning of energy efficiency studies in economics places it in the middle of the nineteenth century, when improved knowledge of thermodynamic principles enabled more efficient manufacturing operations. Numerous observers, including economists, took an interest in energy throughout the industrial revolution of the late 18th and early 19th centuries, namely in relation to the use of fossil fuels such as peat, coal, gas, and oil[15]. Thus, a predominance of macroeconomic views on aggregate output and worries about resource scarcity defined the early years of energy efficiency economics. The book The Coal Question (1865) by W. Stanley Jevons, in which he voiced worries about the trajectory of British industrialisation in light of the country's heavy reliance on coal resources that are becoming ever more limited, is widely seen as a seminal work in the field[16].

- *The Modern Age (1970s–1990s)*

From the 1930s through the 1970s, the classical era of energy efficiency in economics progressively faded away. With the exception of a handful of research initiatives, the widespread usage of energy resources in the post-war period was driven by the affordability of energy [17]. From a more holistic perspective, the energy efficiency problem did not jump out. Not even that area, which made use of more complex tools like econometrics, managed to make significant strides forward; it wasn't until the 1960s that researchers began applying Hotelling's 1931 model of exhaustible resource extraction to make real headway, particularly in the study of fossil fuels.

- *The Contemporary Age (Since the 2000s)*

There was still a lack of theoretical consolidation and practical testing of the energy efficiency gap in the late 1990s. As a result of two connected changes brought about by this agenda, energy efficiency went from being a specialised concern to a more prevalent one in economic analysis. Prompt theoretical critiques emerged, arguing that an overemphasis on market failures obscured important behavioural and institutional dynamics[18]. A break from the premise of perfect reason might potentially be the explanation for large implicit discount rates.

At the same time, behavioural economics was quickly becoming a prominent subfield of economics, with prominent figures such as Herbert Simon (1979), Daniel Kahneman (2002), and Richard Thaler (2017) receiving the Nobel Prize in Economic Sciences in Memory of Alfred Nobel. In behavioural economics, the so-called "internalities" are the discrepancies between the expected benefit of an action and the actual utility that results from it. Richard Thaler and Cass Sun Stein have introduced a novel approach to policy intervention known as nudge to tackle internalities. The goal is to assist individuals in making decisions that are more in line with their own desires[19].

III. MARKET TRENDS IN ENERGY EFFICIENCY

An emerging sector of the economy, industrial energy-efficiency services aim to maximise efficiency in industrial processes by reducing energy consumption and associated costs while simultaneously reducing their impact on the environment [20]. Strict regulations are being enacted by governments worldwide to reduce carbon emissions and promote energy efficiency in business. Innovations in energy management systems, the IoT, and smart grids allow for more precise tracking and optimisation of energy use.

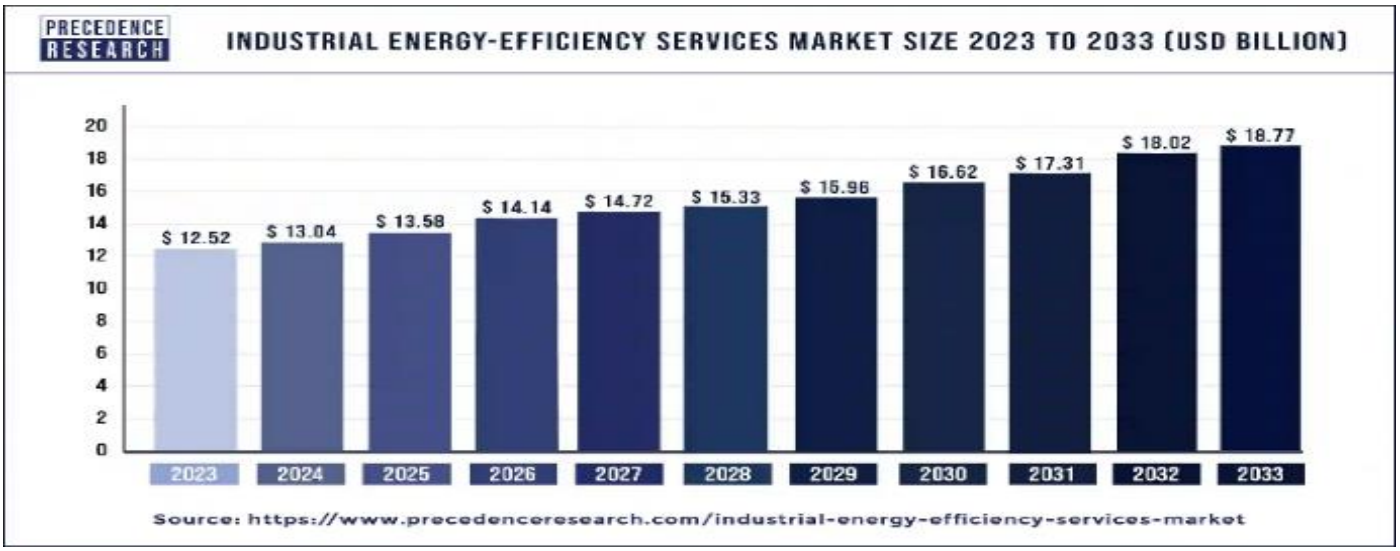

Fig 1 Energy Efficiency Market Services

There are a number of factors, including technology, regulations, and the economy, that point to a bright future for the industrial energy-efficiency services industry. As long as sustainability and cost-cutting remain key priorities, the industry will keep growing and will attract investment from industrial sectors worldwide. [17] Energy management systems are expected to be enhanced by these technologies, which will provide them more predictability and flexibility [21]. The expansion of microgrids and distributed energy resources will support the industrial energy-efficiency services market. Enhanced cooperation among industrial businesses, service providers, and technology providers will create comprehensive energy efficiency solutions. Certain areas lack knowledge regarding the advantages and prospects associated with energy efficiency.

A. Energy-Efficiency Services Market Growth

The success and long-term effects of energy efficiency initiatives, associated practices, and technology are greatly enhanced in an enabling market context, as mentioned before under Indicators. There are six main components to the energy efficiency market circumstances that ICF and USAID have identified (see Figure 2) [22]. By removing many of the usual obstacles, bolstering the market with each of these components encourages market transformation and scaling of energy efficiency. Powerful energy efficiency is linked to certain market traits including legislation, data, and technological know-how [23]. Infrastructure and support for energy efficiency initiatives may be better provided by a thorough evaluation of the possibilities to improve each of these areas, which in turn can have a stronger influence on energy savings and emission reductions.

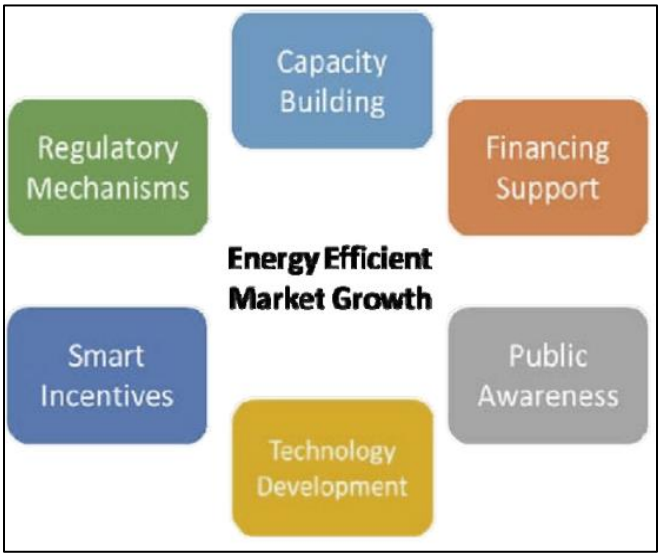

Fig 2 Building Blocks for Energy Efficiency[24]

- *Capacity Building*

Capacity building refers to the development of a local network that supports energy efficiency improvements[25]. This includes trained professionals for energy audits, technicians for installing and servicing energy-efficient systems, and mechanisms for ongoing workforce training and certifications to keep up with advances in the field.

- *Financing Support*

Banks and other lenders are willing to back energy efficiency projects because they see a return on investment. Building renovations, for instance, may greatly reduce running costs during periods of high power tariffs and ultimately provide a profit for owners, even if many efficiency measures are quite inexpensive. Government spending on new power generation is reduced because to customer savings made possible via loans and other forms of financial assistance [24].

- *Technology Development*

The energy efficiency market can only be transformed via the advancement of technology. It ensures that efficient products are identifiable[26], reliable, and affordable. This requires infrastructure for testing, labelling, and certification, either through in-country or regional programs. Promoting these technologies and labels, along with showcasing their local applications, is vital for success.

- *Smart Incentives*

Purchasing and implementing energy-efficient goods and services, such as building audits, may be facilitated by smart incentives like subsidies or rebates [27]. These incentives are especially effective for new or unfamiliar technologies, helping overcome initial cost barriers. They are phased out as technologies gain acceptance and consumers recognize their long-term value[28].

- *Public Awareness*

Public awareness of energy efficiency is crucial for market growth. Consumers, including homeowners, businesses, and the public sector, invest in efficiency improvements across various sectors. It's important that they understand the cost and environmental benefits of efficiency and are informed about effective strategies to enhance energy use in their buildings and services.

- *Regulatory Mechanisms and policies*

Energy audit requirements, product and appliance standards, codes for buildings, and energy efficiency goals at the national or regional level are all examples of regulatory mechanisms and policies that help make energy use more efficient [29]. These work well to persuade the market to embrace energy-efficient building designs, operational procedures, and technology.

B. Challenges of Energy Efficiency in U.S

Numerous promising prospects persist, and the American economy has achieved considerable energy efficiency since the oil shocks of the 1970s. Therefore, the most pressing issue facing the country is how to scale up initiatives like these and make the most of the positive NPV that is already available [30]. Difficulties in capturing efficiency stem from both the characteristics of efficient energy use and customer behaviour [31]. There are system-level obstacles to pursuing energy efficiency prospects on a large scale in our economy, and there are also substantial impediments around every cluster of promise, which contribute to the nation's uneven performance in increasing energy efficiency. Saving money on energy isn't easy to do for four main reasons, some of which are the result of our past approaches to the problem:

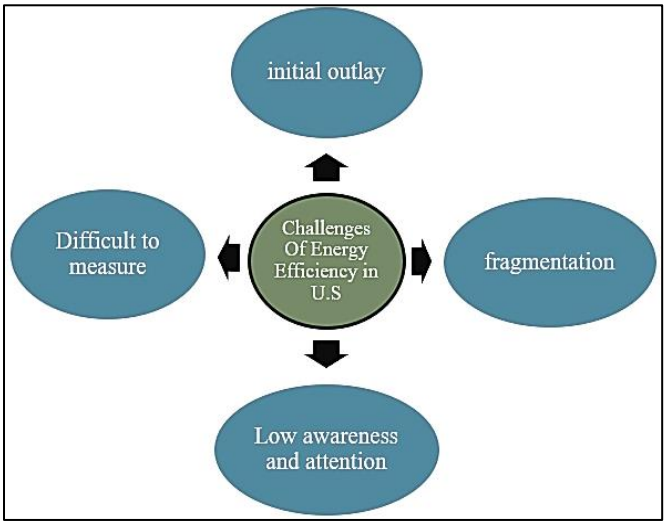

Fig 3 Challenges of Energy efficiency in U.S

➢ *Initial Outlay*

Energy efficiency improvements will cost money up front, but the savings will come over time, possibly for a long time [32]. The investments highlighted in this research offer positive NPVs, but consumers have not been able to capture significant levels of efficiency due to behavioural obstacles to upfront capital expenditures and historically low savings rates.

➢ *Fragmentation*

Energy efficiency potential are not concentrated in any one sector, building type, population cluster, climatic location, or end-use; rather, they are dispersed throughout the economy [33][34]. Because of the dispersion, even if there is a huge potential for energy efficiency with a positive NPV, the individual efficiency opportunities are not very important.

➢ *Low Awareness and Attention*

Energy suppliers prioritise dependability, corporations have other strategic priorities, and residential end-users sometimes have to choose conflicting demands for their resources [35]. With the exception of the energy services company (ESCO) industry, which is a tiny subset of the energy sector, very few organisations have previously targeted these potential [36]. When choosing energy-consuming gadgets, dependability, shape, and usefulness usually take precedence over energy efficiency [37].

➢ *Difficult to Measure*

Saving energy is not a tangible good and is thus not always easy to quantify. Energy savings need more complex measurement and verification procedures than meter readings alone can provide because to the wide variety of variables that impact usage, such as climate, economic activity, and customer behaviour[38].

IV. U.S. ENERGY EFFICIENT BUILDINGS MARKET TRENDS

The U.S. market for energy-efficient buildings is expected to expand significantly throughout the projected period. Sustainable building is receiving funding from the US government. One example is the USD 2.00 billion in federal building projects across 39 states that would employ sustainable materials to reduce carbon emissions. These projects were announced in November 2023 by the U.S. government. This is likely to lead to a surge in the demand for environmentally friendly structures in the U.S.[39]. As a result, many IoT applications prioritise energy efficiency. Nevertheless, the majority of the current literature disregards energy efficiency in favour of sum rate maximisation. So, it's important to look into energy efficiency measures like energy harvesting and reducing energy use[40].

➢ *Energy Efficiency in Buildings*

Policies and programs aimed at lowering building energy usage [41]. Governments and policymakers worldwide have responded to the growing demand for building energy by enacting policies and programs to improve building energy efficiency and decrease consumption. One can broadly classify these policies into three groups, each with its own distinct characteristics:

- Measures with a regulatory component, such as construction codes, which have obligatory elements and minimum standards [42].
- Soft instruments surpass regulatory criteria; they mostly comprise voluntary standards like certifications.
- Financial incentive that is used to encourage building owners and tenants to renovate or rebuild their structures for better energy efficiency, like: Performance contracting for energy savings, Tax breaks, Grants, subsidised loans, and capital subsidies[43].

It is challenging to monitor and evaluate the political growth of the legislative framework for constructing energy policies without specialised technical understanding. Consequently, this part will mostly focus on outlining a few well-established standards and measures[44], providing examples, and discussing the energy and economic effects in a few chosen nations. The implementation of these policies encountered many obstacles, as detailed in the study [45].

➢ *Opportunities in the Energy Efficiency Market*

The energy efficiency market is booming with opportunities, driven by the global push towards sustainability and reducing carbon emissions[46]. Here are some key areas where opportunities are emerging shows in figure 4:

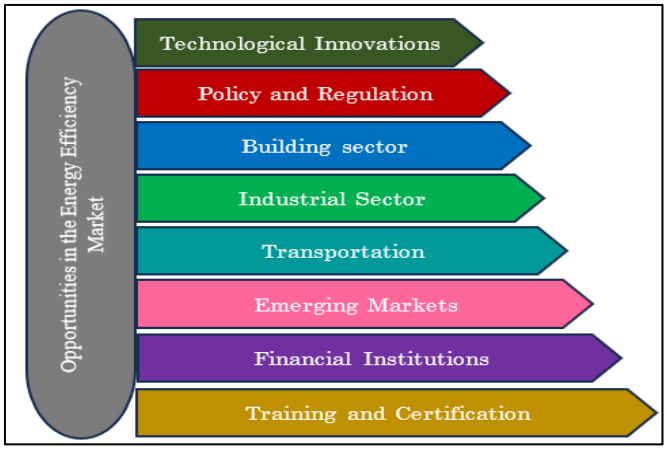

Fig 4 Opportunities in the Energy Efficiency Market

- **Technological Innovations**: Advances in energy-efficient technologies, such as LED lighting, smart thermostats, and high-efficiency HVAC systems, are creating new markets and demand [47].
- **Policy and Regulation:** Governments around the world are implementing policies and regulations to promote energy efficiency[48]. This includes incentives for businesses and homeowners to adopt energy-efficient practices and technologies.
- **Building Sector:** Energy efficiency in buildings is a major focus, with opportunities in retrofitting existing buildings, improving insulation, and adopting energy-efficient building materials and designs[49].
- **Industrial Sector:** Industries are looking to improve their energy efficiency through better process management, equipment upgrades, and adopting energy management systems[50].
- **Transportation:** The shift towards electric vehicles (EVs) and the development of more efficient transportation systems are creating significant opportunities in the energy efficiency market[51].
- **Emerging Markets:** Countries in regions like Africa, the Middle East, and South America are seeing increased investment in energy efficiency, driven by growing energy demands and the need to reduce energy costs[52].
- **Financial Institutions:** There is a growing market for financing energy efficiency projects, with banks and financial institutions offering loans and other financial products to support these initiatives [53].
- **Training and Certification:** As the demand for energy-efficient solutions grows[54], so does the need for trained professionals and certified products, creating opportunities in education and certification services.

V. LITERATURE REVIEW

This section provides the background study on the market trends analysis for energy efficiency using multiple techniques and methods.

In the research Ratsame and Chansri, (2024) Analysis of Electrical Energy Consumption Efficiency Trends using Visualisation Tools, using the Power BI program to display the results on the dashboard page on Power BI, which can display the results of energy consumption in real time and can analyze complex data. Using Power BI displays the Dashboard page. It was found that in Phase 1, during weeks 1–54, there were no energy conservation measures, with a value of Productive Dependent Energy Consumption (PEC), equal to 18.32 kWh Unproductive Energy Consumption (UEC), equal to 308.14 kWh. And in Phase 2, during weeks 54-108, measures were set. Energy conservation has a PEC value of 9.27 kWh and a UEC value of 117.75 kWh, resulting in a PEC reduction of 49.40%. By following these steps and leveraging Power BI's capabilities, you can gain valuable insights into your electrical energy use, forecast future trends, and identify areas for significant efficiency improvements [55].

In Alberizzi and Zani, (2024) analyses carried out is to evaluate the efficiency gains of a hybrid market like SIDC with a focus of this study on the 2020 French market data. The statistical analyses show that, despite the availability of half-hourly products for trading, agents tend to prefer trading on an hourly basis, given the convenience of finding profitable matches. Furthermore, agents often place bids at the median price point during continuous trading to facilitate successful matches. Another noteworthy observation concerns price volatility, which exhibits a notable increase during the final hours of the market [56].

The article Yotov, Hadzikolev and Hadzikoleva, (2020) reports the findings of studies performed on these two metrics; the focus of the investigation was the energy infrastructure of the Bulgarian Republic. We offer mathematical models that investigate the trend model with time series and use artificial neural networks to predict the economy's energy intensity. Additionally, using GDP and energy intensity data, a neural network model has been created to forecast the end energy consumption [57].

In this paper, Hafeez and Dalvi, (2017) explore different energy efficiency policies implemented globally through the market. More and more countries are beginning to recognise that market-based policy instruments can improve energy efficiency more effectively and with more leeway than older, more rigid methods. Increasingly, governments are enacting energy-efficiency regulations that heavily emphasise efficiency as a means to strengthen the institutional framework for such measures [58].

This paper Li *et al.*, (2021) researches the structure and operation of the energy internet, classifying it into 4 layers: application, integrated energy management big data platform, energy transmission, and energy production and consumption. Simultaneously, a workable solution to the energy system's inefficient energy use is suggested by integrating it with new technologies including the internet, smart grid, cloud computing, and big data. This provides a foundation for forecasting the energy internet's trajectory of development and for proposing, from a variety of perspectives, a central area of focus for future energy internet research and development [59].

This study Tseng *et al.*, (2020) using the updated Divisia Index Model from 2001 to 2015, to investigate the driving factors affecting Shandong's energy efficiency. First, energy-saving policies are the main reason why Shandong's energy intensity has been reduced, particularly in the secondary sector, according to this research. Secondly, from 2001 to 2015, the reduction of energy intensity in Shandong was constantly propelled by the improvement of energy efficiency. Lastly, industrial structure has been having an ever-increasing impact on lowering energy intensity since 2006 [60].

Table 1 summarizes key research studies on energy efficiency trends, highlighting their focus, methodologies, challenges, and future directions. The studies explore diverse topics, from real-time consumption analysis and hybrid market efficiency to advanced energy forecasting models and policy evaluations.

ISSN No:-2456-2165

Table 1 Comparative Analysis of Research Studies on Energy Efficiency Trends and Approaches

Reference	Focus	Approach	Challenges	Future Work
Ratsame and Chansri (2024)	Electrical energy consumption efficiency trends and real-time analysis using Power BI	Visualization of energy consumption data using Power BI dashboard; analysis of PEC and UEC values	Lack of energy conservation measures in Phase 1; complex data analysis	Enhance real-time forecasting and integrate more advanced analytics tools for deeper efficiency insights
Alberizzi and Zani (2024)	Efficiency gains in hybrid markets like SIDC, focusing on the 2020 French market	Statistical analysis of trading behaviors; evaluation of price volatility during market's final hours	Preference for hourly over half-hourly products; increased price volatility in final trading hours	Extend analysis to other markets and timeframes to generalize findings
Yotov, Hadzikolev, and Hadzikoleva (2020)	Forecasting energy intensity and consumption trends in Bulgaria using mathematical models	Trend models with time series; artificial neural networks for predicting final energy consumption	Limited to Bulgarian energy systems; data dependency on GDP and energy intensity	Expand the model to incorporate more diverse datasets and cross-country comparisons
Hafeez and Dalvi (2017)	Market-based policies for global energy efficiency	Review of market-based policy instruments; emphasis on energy-efficiency laws	Difficulty in transitioning from traditional to market-based approaches; institutional barriers	Strengthen institutional frameworks and explore new policy designs
Li et al. (2021)	Development and functional framework of the energy internet	Integration of energy systems with emerging technologies like IoT, smart grids, cloud computing, big data	Complexity in implementing integrated technologies; low baseline efficiency of energy systems	Focus on the development of energy internet layers and application-specific advancements
Tseng et al. (2020)	Changing energy efficiency in Shandong using the revised Divisia Index Model (2001–2015)	Quantitative assessment of energy-saving policies and industrial structure effects on energy efficiency	Measuring industrial structure's increasing contribution; tracking long-term effects of policies	Explore sector-specific strategies to boost energy efficiency in different industrial domains

VI. CONCLUSION AND FUTURE WORK

An investigation of internal and external factors influencing ultimate energy consumption is used to estimate the energy service market's operational efficiency. Optimising energy use and tapping into the potential for efficiency improvements can be achieved through scientific evaluation of transportation energy efficiency service demands. This paper highlights the challenges, trends, and opportunities in advancing energy efficiency, particularly in the U.S. Despite progress since the 1970s, barriers such as high upfront costs, fragmentation of opportunities, and low awareness persist. However, technological innovations, regulatory measures, and economic incentives are driving growth in the energy efficiency market, particularly in buildings, industries, and transportation. The review emphasizes the role of data-driven tools, like Power BI, in visualizing consumption trends and optimizing efficiency strategies. Addressing these challenges through collaboration and leveraging emerging technologies can unlock the full potential of energy efficiency, fostering a sustainable, low-carbon future.

REFERENCES

[1]. S. C. R. V. Bhavik Patel, Vamsi Krishna Yarlagadda, Niravkumar Dhameliya, Kishore Mullangi, “Advancements in 5G Technology: Enhancing Connectivity and Performance in Communication Engineering,” Eng. Int., vol. 10, no. 2, pp. 117–130, 2022.

[2]. S. Copiello, E. Donati, and P. Bonifaci, “Energy efficiency practices: A case study analysis of innovative business models in buildings,” Energy Build., vol. 313, no. December 2023, p. 114223, 2024, doi: 10.1016/j.enbuild.2024.114223.

[3]. X. Xu and C. fei Chen, “Energy efficiency and energy justice for U.S. low-income households: An analysis of multifaceted challenges and potential,” Energy Policy, vol. 128, no. January, pp. 763–774, 2019, doi: 10.1016/j.enpol.2019.01.020.

[4]. S. A. and A. Tewari, “AI-Driven Resilience: Enhancing Critical Infrastructure with Edge Computing,” Int. J. Curr. Eng. Technol., vol. 12, no. 02, pp. 151–157, 2022, doi: https://doi.org/10.14741/ijcet/v.12.2.9.

[5]. V. S. Jubin Thomas, Kirti Vinod Vedi, Sandeep Gupta, "A Survey of E-Commerce Integration in Supply Chain Management for Retail and Consumer Goods in Emerging Markets," J. Emerg. Technol. Innov. Res, vol. 10, no. 12, pp. h730–h736, 2023.
[6]. J. Malinowski and B. Hoyt, "Review of upcoming motor efficiency regulations in U.S.," Rec. Conf. Pap. - Annu. Pet. Chem. Ind. Conf., no. February, pp. 2–4, 2013, doi: 10.1109/PCICon.2013.6666013.
[7]. and E. P. de L. G. C. Saldanha, S. E. Gouvea da Costa, "Energy efficiency frameworks," Energy Effic. Fram. a Lit. Overv., no. 1996, pp. 1–10, 2016.
[8]. V. S. Thokala, "A Comparative Study of Data Integrity and Redundancy in Distributed Databases for Web Applications," Int. J. Res. Anal. Rev., vol. 8, no. 4, pp. 383–389, 2021.
[9]. K. Ullah et al., "Ancillary services from wind and solar energy in modern power grids: A comprehensive review and simulation study," J. Renew. Sustain. Energy, vol. 16, no. 3, 2024, doi: 10.1063/5.0206835.
[10]. A. Goyal, "Optimising Cloud-Based CI / CD Pipelines : Techniques for Rapid Software Deployment," TIJER, vol. 11, no. 11, pp. 896–904, 2024.
[11]. I. Sotnyk, T. Kurbatova, G. Trypolska, I. Sokhan, and V. Koshel, "Research trends on development of energy efficiency and renewable energy in households: A bibliometric analysis," Environ. Econ., vol. 14, no. 2, pp. 13–27, 2023, doi: 10.21511/EE.14(2).2023.02.
[12]. K. V. V. and S. G. Jubin Thomas , Piyush Patidar, "An analysis of predictive maintenance strategies in supply chain management," Int. J. Sci. Res. Arch., vol. 06, no. 01, pp. 308–317, 2022, doi: DOI: https://doi.org/10.30574/ijsra.2022.6.1.0144.
[13]. A. P. A. Singh, "Streamlining Purchase Requisitions and Orders : A Guide to Effective Goods Receipt Management," J. Emerg. Technol. Innov. Res., vol. 8, no. 5, pp. g179–g184, 2021.
[14]. R. Arora, S. Gera, and M. Saxena, "Mitigating security risks on privacy of sensitive data used in cloud-based ERP applications," in Proceedings of the 2021 8th International Conference on Computing for Sustainable Global Development, INDIACom 2021, 2021. doi: 10.1109/INDIACom51348.2021.00081.
[15]. Sahil Arora and Apoorva Tewari, "Zero trust architecture in IAM with AI integration," Int. J. Sci. Res. Arch., vol. 8, no. 2, pp. 737–745, Apr. 2023, doi: 10.30574/ijsra.2023.8.2.0163.
[16]. P. Khare, "The Impact of AI on Product Management : A Systematic Review and Future Trends," vol. 9, no. 4, 2022.
[17]. Abhinav Parashar A Singh and Neepakumari Gameti, "Digital Twins in Manufacturing: A Survey of Current Practices and Future Trends," Int. J. Sci. Res. Arch., vol. 13, no. 1, pp. 1240–1250, Sep. 2024, doi: 10.30574/ijsra.2024.13.1.1705.
[18]. R. Goyal, "The Role Of Business Analysts In Information Management Projects," Int. J. Core Eng. Manag., vol. 6, no. 9, pp. 76–86, 2020.
[19]. L. G. Giraudet and A. Missemer, "The history of energy efficiency in economics: Breakpoints and regularities," Energy Res. Soc. Sci., vol. 97, no. February 2022, 2023, doi: 10.1016/j.erss.2023.102973.
[20]. P. Khare and S. Srivastava, "AI-Powered Fraud Prevention: A Comprehensive Analysis of Machine Learning Applications in Online Transactions," J. Emerg. Technol. Innov. Res., vol. 10, pp. f518–f525, 2023.
[21]. M. Z. Hasan, R. Fink, M. R. Suyambu, and M. K. Baskaran, "Assessment and improvement of intelligent controllers for elevator energy efficiency," in IEEE International Conference on Electro Information Technology, 2012. doi: 10.1109/EIT.2012.6220727.
[22]. IEA, Energy Efficiency Governance - Handbook. 2010.
[23]. RCREEE, "Arab Future Energy Index," Igarss 2014, 2014.
[24]. C. Haack, H. Khan, and A. Khan, "Getting Attention for Energy Efficiency in Emerging Markets," ACEEE Summer Study Energy Effic. Build., pp. 1–12, 2016.
[25]. S. C. R. Vennapusa, T. Fadziso, D. K. Sachani, V. K. Yarlagadda, and S. K. R. Anumandla, "Cryptocurrency-Based Loyalty Programs for Enhanced Customer Engagement," Technol. \& Manag. Rev., vol. 3, pp. 46–62, 2018.
[26]. P. K. and S. Arora, "THE IMPACT OF MACHINE LEARNING AND AI ON ENHANCING RISK-BASED IDENTITY VERIFICATION PROCESSES," Int. Res. J. Mod. Eng. Technol. Sci., vol. 06, no. 05, pp. 8246–8255, 2024.
[27]. S. shrivastava Khare, Pranav, "Transforming KYC with AI: A Comprehensive Review of Artificial Intelligence-Based Identity Verification," J. Emerg. Technol. Innov. Res., vol. 10, no. 12, pp. 525–531, 2023.
[28]. S. K. R. Anumandla, V. K. Yarlagadda, S. C. R. Vennapusa, and K. R. V Kothapalli, "Unveiling the Influence of Artificial Intelligence on Resource Management and Sustainable Development: A Comprehensive Investigation," Technol. \& Manag. Rev., vol. 5, no. 1, pp. 45–65, 2020.
[29]. S. R. Bauskar, C. R. Madhavaram, E. P. Galla, J. R. Sunkara, H. K. Gollangi, and S. K. Rajaram, "Predictive Analytics for Project Risk Management Using Machine Learning," J. Data Anal. Inf. Process., vol. 12, no. 04, pp. 566–580, 2024, doi: 10.4236/jdaip.2024.124030.
[30]. P. K. V. and M. R. Suyambu, "A Study on Energy Management Systems (EMS) in Smart Grids Industry," Int. J. Res. Anal. Rev., vol. 10, no. 02, pp. 558–563, 2023.
[31]. N. G. Abhinav Parashar, "Asset Master Data Management: Ensuring Accuracy and Consistency in Industrial Operations," IJNRD - Int. J. Nov. Res. Dev., vol. 9, no. 9, pp. 861-a867, 2024.
[32]. V. V Kumar, M. Tripathi, S. K. Tyagi, S. K. Shukla, and M. K. Tiwari, "An integrated real time optimization approach (IRTO) for physical programming based redundancy allocation problem," Proc. 3rd Int. Conf. Reliab. Saf. …, no. August, 2007.

[33]. R. T. Muhammad Harris Hashmi, Muhammad Affan, "A Customize Battery Management Approach for Satellite," 2023 24th Int. Carpathian Control Conf., 2023.
[34]. K. Mullangi, N. D. Vamsi Krishna Yarlagadda, and M. Rodriguez, "Integrating AI and Reciprocal Symmetry in Financial Management: A Pathway to Enhanced Decision-Making," Int. J. Reciprocal Symmetry Theor. Phys., vol. 5, no. 1, pp. 42–52, 2018.
[35]. S. Bauskar, "BUSINESS ANALYTICS IN ENTERPRISE SYSTEM BASED ON APPLICATION OF ARTIFICIAL INTELLIGENCE," Int. Res. J. Mod. Eng. Technol. Sci., vol. 04, no. 01, pp. 1861–1870, 2022, doi: DOI : https://www.doi.org/10.56726/IRJMETS18127.
[36]. P. K. Vishwakarma and M. R. Suyambu, "Data Analytics In Smart Grid With Renewable Energy Integration," IJSART, vol. 10, no. 10, 2024.
[37]. V. V. Kumar, A. Sahoo, and F. W. Liou, "Cyber-enabled product lifecycle management: A multi-agent framework," in Procedia Manufacturing, 2019. doi: 10.1016/j.promfg.2020.01.247.
[38]. M. G. Energy, "Unlocking Energy Efficiency in the U.S. Economy," Energy, 2009.
[39]. J. J. M. Antunes, J. C. Neves, L. R. C. Elmor, M. F. R. De Araujo, P. F. Wanke, and Y. Tan, "A new perspective on the U.S. energy efficiency: The political context," Technol. Forecast. Soc. Change, vol. 186, no. PA, p. 122093, 2023, doi: 10.1016/j.techfore.2022.122093.
[40]. H. D. Saunders et al., "Energy Efficiency: What Has Research Delivered in the Last 40 Years?," Annu. Rev. Environ. Resour., vol. 46, pp. 135–165, 2021, doi: 10.1146/annurev-environ-012320-084937.
[41]. R. K. Arora, A. Tiwari, and Mohd.Muqeem, "Advanced Blockchain-Enabled Deep Quantum Computing Model for Secured Machine-to-Machine Communication." Sep. 2024. doi: 10.21203/rs.3.rs-5165842/v1.
[42]. V. V. Kumar, S. R. Yadav, F. W. Liou, and S. N. Balakrishnan, "A digital interface for the part designers and the fixture designers for a reconfigurable assembly system," Math. Probl. Eng., 2013, doi: 10.1155/2013/943702.
[43]. P. K. V. Suyambu, Muthuvel Raj, "An Efficient Machine Learning Based Solutions for Renewable Energy System," Int. J. Res. Anal. Rev., vol. 9, no. 4, pp. 951–957, 2022.
[44]. M. Z. Hasan, R. Fink, M. R. Suyambu, M. K. Baskaran, D. James, and J. Gamboa, "Performance evaluation of energy efficient intelligent elevator controllers," in IEEE International Conference on Electro Information Technology, 2015. doi: 10.1109/EIT.2015.7293320.
[45]. A. Allouhi, Y. El Fouih, T. Kousksou, A. Jamil, Y. Zeraouli, and Y. Mourad, "Energy consumption and efficiency in buildings: Current status and future trends," J. Clean. Prod., vol. 109, pp. 118–130, 2015, doi: 10.1016/j.jclepro.2015.05.139.
[46]. V. M. Natakam, M. Nizamuddin, J. G. Tejani, V. K. Yarlagadda, D. K. Sachani, and R. K. Karanam, "Impact of Global Trade Dynamics on the United States Rubber Industry," Am. J. Trade Policy, vol. 9, no. 3, pp. 131–140, Dec. 2022, doi: 10.18034/ajtp.v9i3.716.
[47]. V. N. Boddapati, E. P. Galla, J. R. Sunkara, S. Bauskar, and R. Madhavaram, "Harnessing the Power of Big Data: The Evolution of AI and Machine Learning in Modern Times," ESP J. Eng. Technol. Adv., vol. 1, pp. 134–146, 2021, doi: 10.56472/25832646/JETA-V1I2P116.
[48]. K. Mullangi et al., "AI-Augmented Decision-Making in Management Using Quantum Networks," Asian Bus. Rev., vol. 13, no. 2, pp. 73–86, Aug. 2023, doi: 10.18034/abr.v13i2.718.
[49]. K. Patel, "Quality Assurance In The Age Of Data Analytics: Innovations And Challenges," Int. J. Creat. Res. Thoughts, vol. 9, no. 12, pp. f573–f578, 2021.
[50]. V. V Kumar, M. Tripathi, M. K. Pandey, and M. K. Tiwari, "Physical programming and conjoint analysis-based redundancy allocation in multistate systems: A Taguchi embedded algorithm selection and control (TAS&C) approach," Proc. Inst. Mech. Eng. Part O J. Risk Reliab., vol. 223, no. 3, pp. 215–232, Sep. 2009, doi: 10.1243/1748006XJRR210.
[51]. J. R. Sunkara, S. Bauskar, C. Madhavaram, E. P. Galla, and H. K. Gollangi, "Data-Driven Management: The Impact of Visualization Tools on Business Performance," https//iaeme.com/Home/journal/IJM 1290 Ed. Int. J. Manag., vol. 12, no. 3, pp. 1290–1298, 2021.
[52]. V. K. Yarlagadda, "Cutting-edge developments in Robotics for Smart Warehousing and Logistics Optimization," Robot. Xplore USA Autom. Dig., vol. 1, no. 1, pp. 61–79, 2024.
[53]. R. Arora, A. Kumar, and A. Soni, "AI-Driven Self-Healing Cloud Systems: Enhancing Reliability and Reducing Downtime through Event- Driven Automation." 2024.
[54]. Vasudhar Sai Thokala, "Efficient Data Modeling and Storage Solutions with SQL and NoSQL Databases in Web Applications," Int. J. Adv. Res. Sci. Commun. Technol., pp. 470–482, Apr. 2022, doi: 10.48175/IJARSCT-3861B.
[55]. P. Ratsame and P. Chansri, "Analysis of Electrical Energy Consumption Efficiency Trends Using Visualization Tools," in 2024 8th International Conference on Power Energy Systems and Applications (ICoPESA), 2024, pp. 333–337. doi: 10.1109/ICOPESA61191.2024.10743458.
[56]. A. Alberizzi and A. Zani, "Analyses of the Outcomes of the Intraday Continuous Trading Market in Europe: The French Case," in 2024 20th International Conference on the European Energy Market (EEM), 2024, pp. 1–5. doi: 10.1109/EEM60825.2024.10608854.

[57]. K. Yotov, E. Hadzikolev, and S. Hadzikoleva, "Forecasting energy efficiency and energy consumption in bulgaria by examining the energy intensity indicator using neural networks," in 2020 21st International Symposium on Electrical Apparatus and Technologies, SIELA 2020 - Proceedings, 2020. doi: 10.1109/SIELA49118.2020.9167069.

[58]. S. F. Hafeez and S. D. Dalvi, "Global trends of energy efficiency programs: 2010 to 2025," in 2017 Asian Conference on Energy, Power and Transportation Electrification, ACEPT 2017, 2017. doi: 10.1109/ACEPT.2017.8168577.

[59]. D. Li, Q. Zou, X. Liu, W. Kong, and J. Meng, "Review on the functional form and development trend of energy internet," in Proceedings - 2021 International Conference on Artificial Intelligence, Big Data and Algorithms, CAIBDA 2021, 2021. doi: 10.1109/CAIBDA53561.2021.00034.

[60]. S.-W. Tseng, P.-H. Huang, S. Habich-Sobiegalla, and Y.-Y. Chen, "Changing Energy Efficiency in Energy-Deficient Shandong, China," in 2020 IEEE 2nd Eurasia Conference on Biomedical Engineering, Healthcare and Sustainability (ECBIOS), 2020, pp. 208–211. doi: 10.1109/ECBIOS50299.2020.9203704.