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Research Article

The Effect of Digital Technologies on Energy Efficiency Policy

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Abstract: Digital tools are becoming increasingly important for creating a more effective energy efficiency policy. By leveraging technology, governments can create data-driven insights into their energy usage and identify areas of improvement. Digital tools also provide the opportunity to automate processes and reduce manual labor costs associated with tracking efficiency measures. Additionally, digital solutions enable stakeholders to collaborate in real-time on initiatives that will help meet environmental goals while increasing cost savings for businesses and consumers alike. Ultimately, digital tools have the potential to revolutionize how we approach energy efficiency policies across all sectors worldwide. The article explores global energy efficiency trends and their implications for clean energy transitions, climate change, economic recovery, and job creation. Analyzing data on policies, technology trends and impacts of the Covid-19 pandemic on energy markets worldwide offers a comprehensive view into how governments can use measures such as stimulus programs to achieve sustainability goals while creating jobs. It is essential reading for anyone interested in understanding energy efficiency's role in achieving global climate objectives.

Keywords: Energy Efficiency; Digital Technologies; Policy; Appliances

1. Introduction

Developing the policy approaches and technologies needed to achieve Net Zero by 2050 requires many approaches. For the global energy system to be decarbonized, it is essential to improve energy efficiency, modify behavior of policy approaches and technologies needed, electrify, and use renewable energy, bioenergy, hydrogen, and hydrogen-based fuels that capture and store carbon dioxide [1]. To mitigate CO2, multiple sectors must be involved, and synergies must be explored holistically. Besides innovation, international collaboration, and digitalization, practical approaches to advancing decarburization will be vital to speeding up clean energy transitions.

Harvesting energy from various sources is one of the most critical roles of energy systems to meet the energy demands of applications. It must be converted from sources to the appropriate forms of energy. The sources of energy can be found in various sectors, such as utilities, industry, buildings, and transportation. It is possible to obtain energy from fossil fuels. Their availability depends on customer demand, i.e., they can be stored when not in use [2]. There is widespread popular support for using renewable energy, particularly solar and wind energy, which provide electricity without giving rise to any carbon dioxide emissions. Using energy storage can benefit energy systems with several advantages, including increased efficiency, better economic performance, and higher penetration of renewable energy [3,4]. Electric systems also depend on energy storage to meet various demands such as load leveling, peak shaving, frequency regulation, dampening oscillations, and improving the overall quality and reliability of the power supply [5,6].

There have been energy storage systems for centuries, and they have improved continuously to attain their current level of development, which is mature for most types of energy storage. Energy storage systems can be classified in several ways, depending on their use. Figure 1 depicts a ragged line plot of the performance of different electrical energy-storage technologies in terms of specific power and specific energy. Consider, for instance, the properties of electrochemical energy storage methods, based on their specific energy and power characteristics [7].

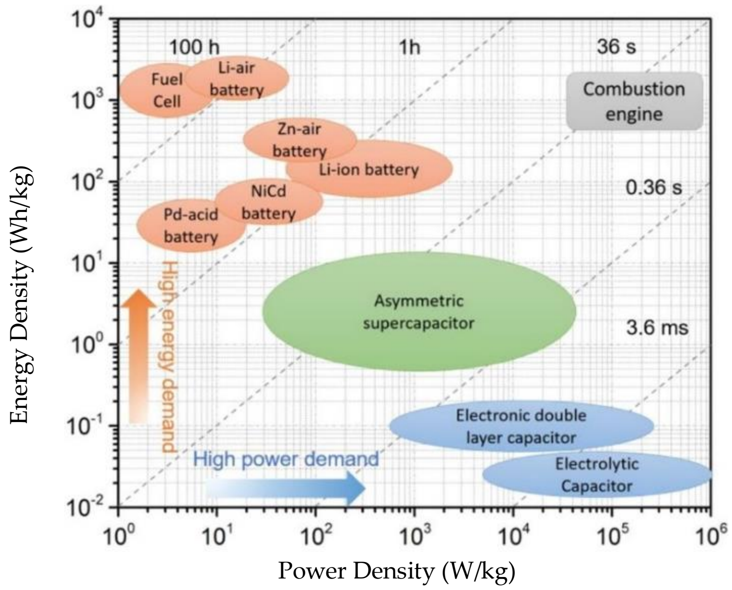

Figure 1. A ragged line plot of the performance of different electrical energy-storage technologies [7].

This study allows each storage type to be identified and contrasted based on its capacity to store energy and its ability to extract energy on demand. It can also be utilized to determine which energy storage option is suitable for specific purposes or requirements. According to the plot, the times shown correspond to discharge time, calculated by dividing the power density by the energy density [7-8]. High energy density devices are necessary for long-term storage of large amounts of generated energy, while high power density devices are essential for short-term discharge periods with rapid fluctuations in charge/discharge cycles. Understanding the differences between these two metrics provides insight into which type of device is best suited to a given application.

The key contribution of the article is to show the application of digital technologies to increase the energy efficiency. This article demonstrated an improvement in the energy intensity of the world in the context of the Net Zero Scenario between 2000 and 2030. In this context, energy efficiency is the single largest measure to avoid energy demand in the Net Zero Emissions by 2050 Scenario, along with the closely related measures of electrification, behavioral change, digitalization and material efficiency. All together these measures shape global energy intensity – the amount of energy required to produce a unit of GDP, a key measure of energy efficiency of the economy. To get on track with the Net Zero Scenario, the rate of improvement in global energy intensity needs to be two to three times higher than historical rates and increase to just over 4% per year between 2020 and 2030.

The remainder of the article is organized as follows: the energy efficiency deals in **Section 2**. Stimulus funds to increase energy efficiency investigates in deals in **Section 3**. Energy efficiency policies and digital technologies appear in **Section 4.** Economic crises address in **Section 5**. Finally, energy-efficient appliances discuss in **Section 6**.

2. Energy efficiency

Energy efficiency is considered the "first fuel" in sustainable energy initiatives, as it enables some of the most rapid and most economically advantageous CO2 reduction opportunities, thereby decreasing energy costs and enhancing energy reliability [9]. Energy efficiency is the primary approach to eliminating energy consumption in the Net Zero Emissions by 2050 envisioned scenario, along with the closely associated approaches of energy efficiency, behavioral shifts, information technology, and resource efficiencies.

These measures contribute to global energy intensity - a measure of economic efficiency that reflects the amount of energy necessary to produce a unit of GDP [10,11]. Overall energy intensity growth must be two to three times greater than previous levels and accelerate to just above 4% annually between 2020 and 2030. Even though most measures to eliminate energy consumption tend to increase the energy intensity, and many do intersect, the energy efficiency of particular technologies. An improvement in the energy intensity of the world in the context of the Net Zero Scenario between 2000 and 2030 is depicted in Figure 2. In 2000, primary energy intensity reached 5.63 MJ per USD of 2021 GDP PPP. In 2005, primary energy intensity reached 5.37 MJ per USD of 2021 GDP PPP. In 2010, primary energy intensity reached 5.06 MJ per USD of 2021 GDP PPP. In 2015, primary energy intensity reached 4.55 MJ per USD of 2021 GDP PPP. In 2020, primary energy intensity reached 4.3 MJ per USD of 2021 GDP PPP. In 2020, primary energy intensity reached 2.9 MJ per USD of 2021 GDP PPP.

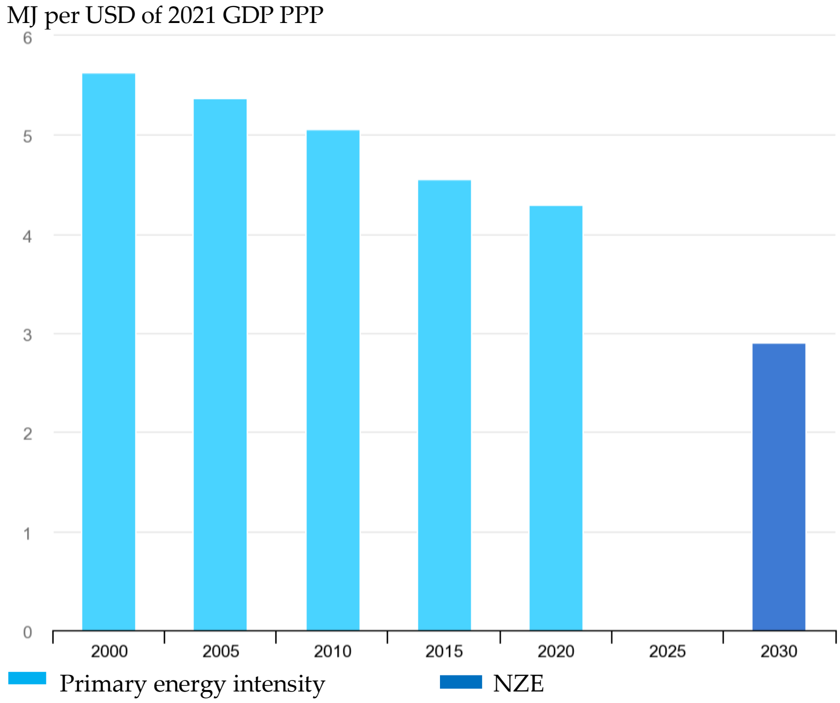

Figure 2. An improvement in the energy intensity of the world in the context of the Net Zero Scenario between 2000 and 2030 [12]

2. Stimulus funds to increase energy efficiency

Furthermore, across all sectors, implementing government stimulus programs developed as part of the Covid-19 recovery plans is expected to significantly influence operational performance by encouraging increased investment in new products, technologies, and organizational restructuring. There will be an impact on energy intensity in both cases. Figure 3 indicates the GDP trends with energy intensity gains, 2000-2020. According to the IEA, governments' stimulus packages have earmarked USD 66 billion for energy efficiency initiatives. It's no surprise that the largest share (USD 26 billion) has been devoted to the construction sector, as improvements in the productivity of buildings are predicted to produce around 15 jobs for every USD 1 million spent. Around USD 20 billion is also being invested in accelerating the switch to electric vehicles and new vehicle charging facilities [13-15].

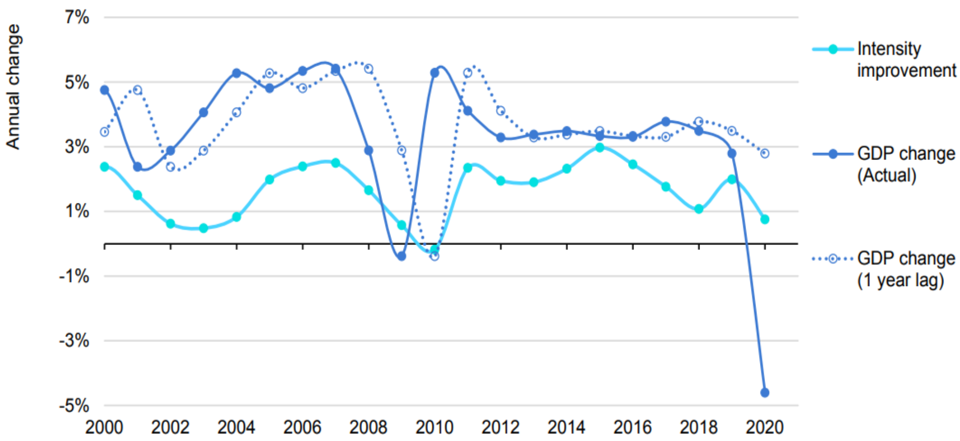

Figure 3. The trends with energy intensity gains, 2000-2020 GDP [15]

3. Energy efficiency policies and digital technologies

A fundamental part of the transition towards net-zero CO2 emissions will be the digital transformation of energy efficiency policies [15]. For illustration, in the case described in recently released reports entitled Net Zero by 2050, global energy consumption in 2050 will be approximately 8% less than the present, despite supporting an economic system twice as massive with 2 billion additional people [16]. To fulfil this, yearly enhancements in energy intensity will be required to triple over the next ten years to achieve 13 Gt of CO2 mitigation by 2030. As energy efficiency is one of the most critical measures needed to meet climate objectives, digitalization's role will be crucial by increasing the reach and scale of energy efficiency via electrification, fuel switching and behavioral adaptations [15]. Digital technologies for energy efficiency policy and ecosystem are demonstrated in Figure 4.

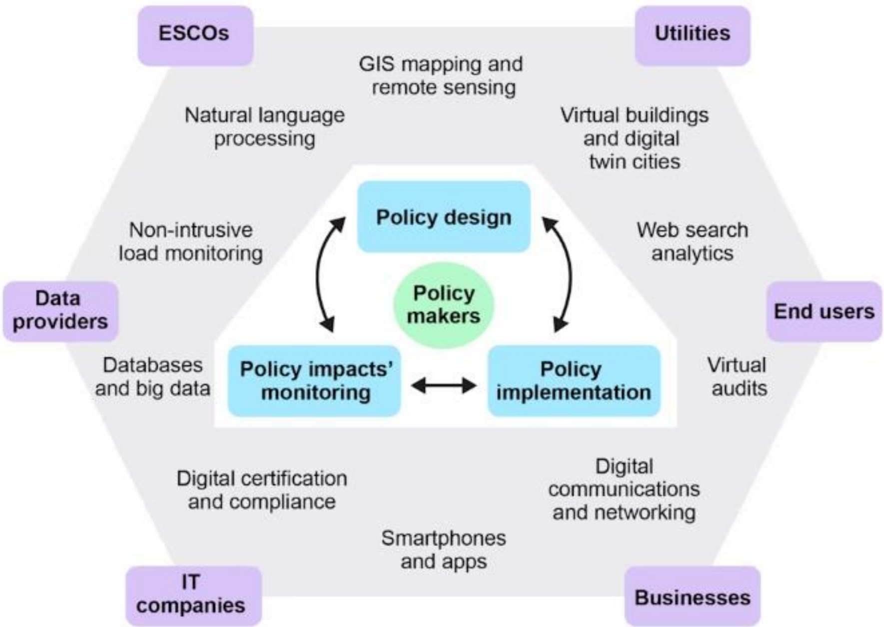

Figure 4. Digital Technologies for energy efficiency policy and ecosystem [15]

A significant opportunity is available to take advantage of digital tools at each stage of the policy development process, including design, development, and monitoring. Their increasingly important role is anticipated to provide policymakers to assess the value of incorporating energy efficiency and alternative energy resources more transparently, to broaden the energy efficiency ecosystem, and to promote new approaches to market-based policy development [16,17].

4. Economic crises

Even though energy intensity does not appear to be an accurate indicator of energy efficiency progress during the ongoing crisis, historical energy intensity statistics and historical economic data can be helpful in forecasting trends following the crisis. The trends in historical GDP and energy intensity data suggest that significant drops in GDP, such as the one in 2020, are followed by smaller future energy intensity increases. Global GDP, for instance, grew by over 5% per year between 2006 and 2007, then fell to 3% in 2008 and zero in 2009. Energy intensity data show corresponding falls in energy intensity improvements in 2008 and 2009, and 2010 when global GDP growth returned to pre-crisis levels of around 5%. Economic recessions can slow down improvements in energy intensity beyond the immediate aftermath of the downturn based on this lag between GDP changes and energy intensity changes. Fig. 4 depicts the GDP trends with energy intensity gains, 2000-2020 [15-20].

5. Energy-efficient appliances

According to Southeast Asian studies, during an economic crisis, households confronting the prospect of joblessness or reduced incomes can be furthermore motivated to seek the most affordable choices when it relates to purchasing appliances [21,22]. In addition to energy-efficient machines often appearing to be more affordable throughout their lifespan, consumers frequently find it challenging to determine the long-term costs of equipment, meaning purchasing options are commonly determined based on the purchase cost alone, a major barrier to improving energy efficiency [23]. Appliance labels can facilitate eliminating this barrier by supplying consumers with details on the energy usage of appliances, which is essential in estimating lifetime expenses [24]. As testing procedures that are more representative of actual life behavior become more common, appliances' energy consumption information is becoming more accurate. Figure 5 represents the purchase price. The lifecycle price concerning the efficiency of air conditioning systems by technological advancement in Viet Nam, 2019, is shown in Figure 6.

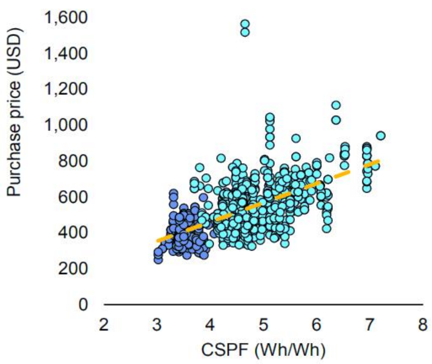

Figure 5. Purchase price

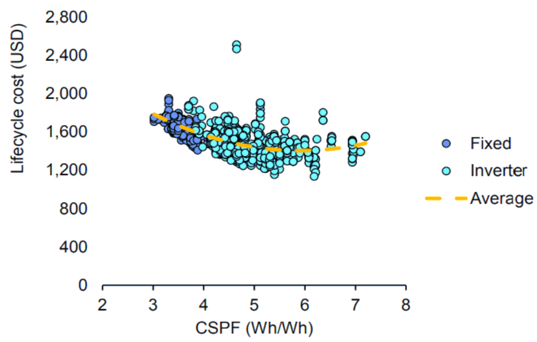

Figure 6. Lifecycle price concerning the efficiency of air conditioning systems by technological advancement in Viet Nam, 2019

The evidence from Southeast Asia indicates that energy-efficient appliances can be more affordable than their less efficient counterparts, even without access to information or the ability to calculate lifecycle costs. For example, Vietnam offers a variety of air conditioner models with seasonal energy efficiency factors of over 530 USD regularly - making them much cheaper than traditional models in terms of purchase price alone. This article demonstrates how energy-efficient appliances can offer significant savings for consumers who do not have the resources or desire to calculate lifecycle costs [25,30].

6. The impact of government stimulus on manufacturing operations and energy Inflation following the global financial crisis

This analysis of the Chinese stimulus measure of CNY 4 trillion (USD 586 billion in 2009) resulting from the 2008-2009 global economic crisis indicates an effect of 4.5% on GDP increases and only 1.8% on energy demand [30]. Several sectors were targeted by the stimulus program, particularly infrastructure, housing, health care, education, and research. The construction industry saw a significant increase in activity over the past decade, resulting in higher output for energy-intensive manufacturing industries such as primary metals and cement [31].

The study has increased production levels more than less energy-intensive sectors such as textiles, machinery, and food and beverages. The increased investment into the construction sector has enabled these energy-intensive industries to grow at an accelerated rate compared to other sectors of the economy, providing further economic stimulus through increased production outputs [32]. Analyzing the effects of the stimulus program in China on the development of manufacturing sectors is presented in Figure 7.

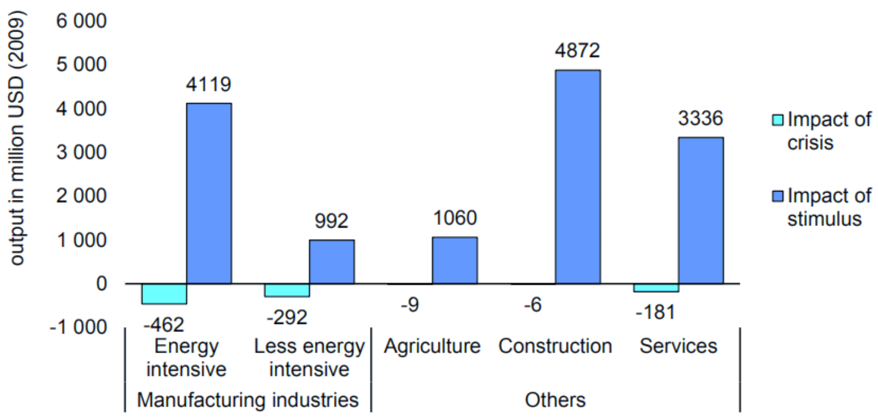

Figure 7. Analyzing the effects of the stimulus program in China on the development of manufacturing sectors [15]

The stimulus package in China had a significant impact on the structure of manufacturing industries. It provided an influx of capital to many Chinese manufacturers, allowing them to invest in new technologies and processes for greater production efficiency and quality control. This increased competitiveness within the industry, leading to improved market share for Chinese companies and higher employee wages. Additionally, it encouraged foreign direct investment into China's manufacturing sector, contributing to economic growth and employment opportunities throughout the country [33].

7. Conclusion

The recent decline in global energy demand growth is a significant shift from the 5% increase seen last year, one of the most significant single-year increases in 50 years. This year's expected 1% growth rate demonstrates an overall decrease and indicates that global energy needs are changing significantly. Companies need to understand these changes and adjust their strategies accordingly to ensure they remain competitive within this evolving landscape. The benefits of energy efficiency are numerous, ranging from reducing carbon emissions to supporting the clean energy transition. Energy not consumed due to efficiency is automatically carbon-free, and efficient electricity use helps speed up the decarbonisation of power sectors while aiding in the integration of renewable energies. A shift from heavy industry to less energy-intensive services can also help increase overall system efficiency and reduce both consumer and import bills for entire countries. Thus, energy efficiency presents a great opportunity that should be taken advantage of by all nations worldwide. Moreover, Digital tools have revolutionized how businesses and organizations approach energy efficiency. By leveraging technology such as artificial intelligence, predictive analytics, and cloud computing to track energy usage patterns across multiple sites in real-time, companies can better understand how their operations use electricity and identify opportunities for improvement. This data can be used to develop more effective policies that prioritize cost savings while also reducing environmental impacts. Additionally, digital tools provide a platform for collaboration between stakeholders on sustainability initiatives which helps ensure collective success in reaching desired goals related to improved energy efficiency.

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References

1. Cachola, C. da S., Ciotta, M., Azevedo dos Santos, A., & Peyerl, D. (2023). Deploying of the carbon capture technologies for CO2 emission mitigation in the industrial sectors. *Carbon Capture Science & Technology*, *7*(100102), 100102.
2. Khaleel, M. M., Adzman, M. R., & Zali, S. M. (2021). An integrated of hydrogen fuel cell to distribution network system: Challenging and opportunity for D-STATCOM. Energies, 14(21), 7073.
3. Mushafiq, M., Arisar, M. M. K., Tariq, H., & Czapp, S. (2023). Energy efficiency and economic policy: Comprehensive theoretical, empirical, and policy review. Energies,16(5), 2381.
4. García-Quevedo, J., & Jové-Llopis, E. (2021). Environmental policies and energy efficiency investments. An industry-level analysis. Energy Policy, 156(112461), 112461.
5. Wen, M., Zhou, C., & Konstantin, M. (2023). Deep neural network for predicting changing market demands in the energy sector for a sustainable economy. Energies, 16(5), 2407.
6. García-Quevedo, J., & Jové-Llopis, E. (2021). Environmental policies and energy efficiency investments. An industry-level analysis. Energy Policy, 156(112461), 112461.
7. Koohi-Fayegh, S., & Rosen, M. A. (2020). A review of energy storage types, applications and recent developments. *Journal of Energy Storage*, *27*(101047), 101047.
8. Apribowo, C. H. B., Sarjiya, S., Hadi, S. P., & Wijaya, F. D. (2022). Optimal planning of battery energy storage systems by considering battery degradation due to ambient temperature: A review, challenges, and new perspective. *Batteries*, *8*(12), 290.
9. Alsharif, A., Tan, C. W., Ayop, R., Smin, A. A., Ahmed, A. A., Kuwil, F. H., & Khaleel, M. M. (2023). Impact of electric Vehicle on residential power distribution considering energy management strategy and stochastic Monte Carlo algorithm. Energies, 16(3), 1358.
10. Khaleel, M. M., Abulifa, S. A., Abdaldeam, I. M., Abulifa, A. A., Amer, M., & Ghandoori, T. M. (2023). A current assessment of the renewable energy industry. African Journal of Advanced Pure and Applied Sciences (AJAPAS), 2(1), 122–127.
11. Wen, M., Zhou, C., & Konstantin, M. (2023). Deep neural network for predicting changing market demands in the energy sector for a sustainable economy. Energies, 16(5), 2407.
12. Howarth, N. (n.d.). Energy Efficiency. Retrieved December 01, 2022, from IEA website: https://www.iea.org/reports/energy-efficiency
13. Alsharif, A., Tan, C. W., Ayop, R., Ahmed, A. A., & Khaleel, M. M. (2022). Electric vehicle integration with energy sources: Problem and solution review. African Journal of Advanced Pure and Applied Sciences (AJAPAS), 17–20.
14. Rosenow, J., Kern, F., & Rogge, K. (2017). The need for comprehensive and well targeted instrument mixes to stimulate energy transitions: The case of energy efficiency policy. Energy Research & Social Science, 33, 95–104.
15. Yang, M., Hong, Y., & Yang, F. (2022). The effects of Mandatory Energy Efficiency Policy on resource allocation efficiency: Evidence from Chinese industrial sector. Economic Analysis and Policy, 73, 513–524.

16. Sung, J., Troilo, M., & Howarth, N. (n.d.). Better energy efficiency policy with digital tools. Retrieved December 01, 2022, from IEA website: https://www.iea.org/articles/better-energy-efficiency-policy-with-digital-tools.
17. Nordt, A., Raven, R., Malekpour, S., & Sharp, D. (2023). The politics of intermediation in transitions: Conflict and contestation over energy efficiency policy. Energy Research & Social Science, 97(102971), 102971.
18. Song, P., Mao, X., Li, Z., & Tan, Z. (2023). Study on the optimal policy options for improving energy efficiency and Co-controlling carbon emission and local air pollutants in China. Renewable and Sustainable Energy Reviews, 175(113167), 113167.
19. A.-C. Orgerie, M. D. de Assuncao, and L. Lefevre, "A survey on techniques for improving the energy efficiency of large-scale distributed systems," ACM Comput. Surv., vol. 46, no. 4, pp. 1–31, 2014.
20. L. Anthopoulos and V. Kazantzi, "Urban energy efficiency assessment models from an AI and big data perspective: Tools for policy makers," Sustain. Cities Soc., vol. 76, no. 103492, p. 103492, 2022.
21. J. Malinauskaite, H. Jouhara, L. Ahmad, M. Milani, L. Montorsi, and M. Venturelli, "Energy efficiency in industry: EU and national policies in Italy and the UK," Energy (Oxf.), vol. 172, pp. 255–269, 2019.
22. Khaleel, M. M. (2023). Intelligent Control Techniques for Microgrid Systems. Brilliance: Research of Artificial Intelligence, 3(1), 56–67.
23. H. Wu, Y. Hao, and S. Ren, "How do environmental regulation and environmental decentralization affect green total factor energy efficiency: Evidence from China," Energy Econ., vol. 91, no. 104880, p. 104880, 2020.
24. H. Sun, B. K. Edziah, C. Sun, and A. K. Kporsu, "Institutional quality, green innovation and energy efficiency," Energy Policy, vol. 135, no. 111002, p. 111002, 2019.
25. M. Economidou, V. Todeschi, P. Bertoldi, D. D'Agostino, P. Zangheri, and L. Castellazzi, "Review of 50 years of EU energy efficiency policies for buildings," Energy Build., vol. 225, no. 110322, p. 110322, 2020.
26. Khaleel, M. M., Ahmed, A. A., & Alsharif, A. (2023a). Artificial Intelligence in Engineering. Brilliance: Research of Artificial Intelligence, 3(1), 32–42.
27. Du, W., Li, M., & Wang, Z. (2022). The impact of environmental regulation on firms' energy-environment efficiency: Concurrent discussion of policy tool heterogeneity. Ecological Indicators, 143(109327), 109327.
28. Zhao, Y., & Mao, J. (2022). Energy effects of non-energy policies: Minimum wage standard and enterprise energy efficiency in China. Resources Policy, 79(102953), 102953.
29. Khaleel, M. M., Mohamed Ghandoori, T., Ali Ahmed, A., Alsharif, A., Ahmed Alnagrat, A. J., & Ali Abulifa, A. (2022). Impact of mechanical storage system technologies: A powerful combination to empowered the electrical grids application. 2022 IEEE 2nd International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering (MI-STA), 628–636. IEEE.
30. Economidou, M., Ringel, M., Valentova, M., Castellazzi, L., Zancanella, P., Zangheri, P., … Bertoldi, P. (2022). Strategic energy and climate policy planning: Lessons learned from European energy efficiency policies. Energy Policy, 171(113225), 113225.
31. Li, B., Han, Y., Wang, C., & Sun, W. (2022). Did civilized city policy improve energy efficiency of resource-based cities? Prefecture-level evidence from China. Energy Policy, 167(113081), 113081.
32. McAllister, P., & Nase, I. (2023). Minimum energy efficiency standards in the commercial real estate sector: A critical review of policy regimes. Journal of Cleaner Production, 393(136342), 136342.
33. Tsemekidi Tzeiranaki, S., Economidou, M., Bertoldi, P., Thiel, C., Fontaras, G., Clementi, E. L., & Franco De Los Rios, C. (2023). "The impact of energy efficiency and decarbonisation policies on the European road transport sector." Transportation Research. Part A, Policy and Practice, 170(103623), 103623.