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Reviewing the impact of energy-efficient appliances on household consumption

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Abstract

This review provides a succinct overview of the review on the impact of energy-efficient appliances on household consumption: Energy-efficient appliances play a pivotal role in mitigating energy consumption and promoting sustainability in households. This review examines the significant impact of energy-efficient appliances on household consumption patterns and energy usage. The review begins by elucidating the importance of energy efficiency in mitigating climate change and reducing carbon emissions. It underscores how household consumption accounts for a substantial portion of total energy usage, making it imperative to explore the role of energy-efficient appliances in curbing energy consumption. Key findings reveal that energy-efficient appliances offer substantial benefits, including reduced energy bills, lower environmental impact, and enhanced comfort and convenience for households. Through advanced technologies and design innovations, these appliances minimize energy wastage while maintaining optimal performance standards. Moreover, the review delves into the diverse range of energy-efficient appliances available to consumers, spanning from refrigerators and washing machines to HVAC systems and lighting fixtures. It examines the energy-saving features and efficiency standards governing these appliances, highlighting their role in promoting sustainable consumption habits among households. Furthermore, the review evaluates the economic and environmental implications of adopting energy-efficient appliances. It explores how energy savings translate into cost reductions for households, contributing to economic resilience and financial well-being. Additionally, it analyzes the environmental benefits, such as reduced greenhouse gas emissions and conservation of natural resources, associated with the widespread adoption of energy-efficient appliances. Challenges and barriers to the widespread adoption of energy-efficient appliances are also scrutinized, including upfront costs, consumer awareness, and market availability. Strategies to overcome these challenges, such as financial incentives, public awareness campaigns, and regulatory frameworks, are discussed to facilitate greater uptake of energy-efficient appliances among households. In conclusion, this review underscores the transformative impact of energy-efficient appliances on household consumption patterns and energy usage. It advocates for continued efforts to promote the adoption of energy-efficient appliances through policy interventions, technological advancements, and consumer education initiatives, ultimately fostering a more sustainable and energy-efficient future for households worldwide.

Keywords: Impact; Energy-Efficient; Appliances; Household; Consumption

1 Introduction

Energy-efficient appliances play a pivotal role in reducing household energy consumption and promoting sustainable living practices. As the world grapples with the challenges of climate change and energy sustainability, the significance of these appliances cannot be overstated (Bhutto, et. al., 2020, Waris & Hameed, 2020, Zou & Mishra, 2020). This review aims to explore the impact of energy-efficient appliances on household consumption, focusing on their role in reducing energy usage, saving costs, and mitigating environmental impact.

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The purpose of this review is to provide a comprehensive analysis of the benefits, challenges, and future prospects of energy-efficient appliances in households. By examining the latest research, case studies, and industry trends, this review seeks to highlight the importance of these appliances in promoting energy efficiency and sustainable living practices.

This review will cover various aspects of energy-efficient appliances, including their definition, types, benefits, standards, adoption rates, and challenges. It will also explore the role of energy labels and standards in guiding consumer choices and driving market transformation towards more energy-efficient products.

Overall, this review aims to provide valuable insights into the impact of energy-efficient appliances on household consumption and to offer recommendations for policymakers, manufacturers, and consumers to promote their widespread adoption. By understanding the benefits and challenges associated with these appliances, stakeholders can work together to accelerate the transition to a more sustainable and energy-efficient future.

2 Overview of Energy-Efficient Appliances

Energy-efficient appliances are designed to consume less energy compared to traditional appliances, thereby reducing overall energy consumption and utility bills. These appliances are designed with various energy-saving features that help them operate more efficiently and effectively. Here, we provide an overview of energy-efficient appliances, including their definition, characteristics, and types (Okoye & Adelakun, 2019, Singh, Henriques & Martins, 2019).

Energy-efficient appliances are appliances that are designed to minimize energy consumption while providing the same level of performance as their less-efficient counterparts. They achieve this by incorporating advanced technologies and design features that reduce energy waste during operation. Characteristics of energy-efficient appliances include: Energy-efficient appliances are often labeled with energy efficiency ratings, such as ENERGY STAR in the United States or EU energy labels in Europe. These ratings indicate the appliance's energy efficiency compared to standard models.

Energy-efficient appliances often utilize advanced technologies, such as variable speed compressors in refrigerators or heat pumps in water heaters, to achieve higher efficiency levels (Mathias, Juenger & Horton, 2023, Shah, Park & Ding, 2021, Wang, Wang & He, 2022). These appliances may include features such as improved insulation, automatic shut-off timers, or sensors that adjust settings based on usage patterns to reduce energy waste. Energy-efficient appliances not only save energy but also reduce greenhouse gas emissions and other pollutants associated with energy production.

Energy-efficient appliances are available for various household applications, including: Energy-efficient refrigerators and freezers use advanced insulation and compressor technology to reduce energy consumption. Energy-efficient washing machines and dryers use less water and electricity per cycle, often incorporating features like load sensors and shorter cycle options. Energy-efficient dishwashers use less water and energy per cycle, often featuring energy-saving modes and sensors that adjust water usage based on load size.

Energy-efficient air conditioners and heaters use advanced heat pump technology and variable speed motors to reduce energy consumption while maintaining comfort levels. Energy-efficient lighting options include LED and CFL bulbs, which use less energy and last longer than traditional incandescent bulbs. Overall, energy-efficient appliances offer significant benefits in terms of energy savings, cost reduction, and environmental impact. As technology continues to advance, the range and efficiency of these appliances are expected to increase, further promoting energy efficiency in households (Enteria, Cuartero-Enteria & Sawachi, 2020, Lun & Tung, 2019, Xiao, et. al., 2022).

3 Significance of Energy Efficiency in Household Consumption

Energy efficiency plays a crucial role in reducing energy consumption and environmental impact associated with household consumption (Bastida, et. al., 2019, Brockway, et. al., 2021, Paramati, Shahzad & Doğan, 2022). This section explores the significance of energy efficiency in household consumption, focusing on its impact on energy usage and environmental sustainability, as well as the role of energy-efficient appliances in achieving these goals.

Household consumption accounts for a significant portion of total energy usage worldwide. The energy used in homes for heating, cooling, lighting, and powering appliances contributes to a substantial portion of overall energy consumption and carbon emissions. The inefficient use of energy in households not only leads to higher energy bills but also increases greenhouse gas emissions and environmental degradation.

Energy-efficient appliances play a critical role in reducing household energy consumption and carbon emissions. These appliances are designed to use less energy while providing the same level of performance as their less-efficient counterparts. By replacing old, inefficient appliances with energy-efficient models, households can significantly reduce their energy bills and environmental impact. Energy-efficient appliances achieve this through various mechanisms, such as: Energy-efficient appliances use advanced technologies, such as inverter compressors in refrigerators or heat pump technology in water heaters, to achieve higher efficiency levels (Javid & Khan, 2020, Li, et. al., 2019, Verma, Kumari & Raghubanshi, 2021).

These appliances often include features like automatic shut-off timers, load sensors, and energy-saving modes that reduce energy waste during operation. By reducing energy consumption, energy-efficient appliances help reduce carbon emissions and other pollutants associated with energy production, contributing to environmental sustainability. Energy-efficient appliances can lead to significant cost savings over time, as they consume less energy and require less maintenance compared to less-efficient models (Aggarwal & Pathak, 2020, Callebaut, et. al., 2021, Islam, Haque & Mahmud, 2021).

In conclusion, energy efficiency is of paramount importance in household consumption, as it helps reduce energy usage, lower energy bills, and mitigate environmental impact. Energy-efficient appliances play a crucial role in achieving these goals by using advanced technologies and energy-saving features to minimize energy waste. Promoting energy efficiency in households through the adoption of energy-efficient appliances is essential for achieving a sustainable and environmentally friendly future.

4 Benefits of Energy-Efficient Appliances

Energy-efficient appliances offer a range of benefits to households, including cost savings, environmental benefits, and enhanced comfort and convenience. This section explores these benefits in detail, highlighting the advantages of using energy-efficient appliances in households. One of the primary benefits of energy-efficient appliances is cost savings for households. Energy-efficient appliances consume less energy than their less-efficient counterparts, leading to lower utility bills over time. By investing in energy-efficient appliances, households can reduce their energy costs and save money in the long run. The energy savings can be substantial, particularly for appliances that consume a lot of energy, such as refrigerators, air conditioners, and washing machines (Dinh & Kim, 2021, McGinley, Moran & Goggins, 2022, Neves & Oliveira, 2021).

Energy-efficient appliances also offer significant environmental benefits. By consuming less energy, these appliances help reduce the demand for electricity, which is often generated from fossil fuels. This, in turn, reduces greenhouse gas emissions and helps mitigate climate change. By using energy-efficient appliances, households can reduce their carbon footprint and contribute to a more sustainable environment (Bhutto, et. al., 2020, Joshi, Sheorey & Gandhi, 2019, Liao, Shen & Shi, 2020).

In addition to cost savings and environmental benefits, energy-efficient appliances also offer enhanced comfort and convenience for users. Many energy-efficient appliances come with advanced features and technologies that improve performance and functionality. For example, energy-efficient air conditioners often provide better temperature control and quieter operation than less-efficient models. Similarly, energy-efficient refrigerators may offer more storage space and better organization options (Aliero, et. al., 2921, Mehmood, et. al., 2019, Šujanová, et. al., 2019).

In conclusion, energy-efficient appliances offer a range of benefits to households, including cost savings, environmental benefits, and enhanced comfort and convenience. By investing in energy-efficient appliances, households can reduce their energy costs, lower their carbon footprint, and enjoy improved performance and functionality. Promoting the use of energy-efficient appliances is essential for achieving a more sustainable and environmentally friendly future.

5 Energy Efficiency Standards and Labels

Energy efficiency standards and labels play a crucial role in promoting energy efficiency and guiding consumer choices (De Ayala, et. al., 2021, Wang, et. al., 2019, Wang, et. al., 2021). This section provides an overview of energy efficiency standards and regulations, as well as the importance of energy labels in guiding consumer decisions. Energy efficiency standards and regulations are rules set by governments or regulatory bodies to ensure that appliances and equipment meet minimum energy performance requirements. These standards are typically based on the energy consumption of the appliance or equipment and are designed to promote the use of more energy-efficient technologies.

Energy efficiency standards can apply to a wide range of products, including household appliances, lighting, heating, cooling, and ventilation systems, as well as industrial equipment. Standards are typically set through legislation or regulatory frameworks and are often updated to reflect advances in technology and improvements in energy efficiency. Energy labels play a crucial role in informing consumers about the energy efficiency of appliances and equipment. These labels provide consumers with valuable information about the energy consumption of a product, allowing them to make informed decisions when purchasing new appliances (Chen, et. al., 2020, Grondzik & Kwok, 2019, Lackner, 2022).

Energy labels typically include information such as the energy efficiency rating of the product, its annual energy consumption, and an estimate of the annual energy cost. Some labels also provide additional information, such as the product's carbon footprint or its energy-saving features. Energy labels help consumers compare the energy efficiency of different products and choose those that offer the best energy performance. By selecting energy-efficient appliances, consumers can reduce their energy bills, save money, and contribute to environmental sustainability by reducing energy consumption and greenhouse gas emissions (Giraudet, 2020, Solà, et. al., 2021, Zhang, Xiao & Zhou, 2020).

In conclusion, energy efficiency standards and labels play a crucial role in promoting energy efficiency and guiding consumer choices. By setting minimum energy performance requirements and providing consumers with information about the energy efficiency of products, these standards and labels help drive the adoption of energy-efficient technologies and contribute to a more sustainable future.

6 Adoption and Uptake of Energy-Efficient Appliances

The adoption and uptake of energy-efficient appliances are influenced by various factors, and overcoming barriers to widespread adoption is crucial for achieving energy efficiency goals (Agyarko, Opoku & Van Buskirk, 2020, Cristino, et. al., 2021, Hesselink & Chappin, 2019). This section explores the factors influencing consumer adoption of energy-efficient appliances and strategies to overcome barriers to their widespread adoption.

Several factors influence consumer adoption of energy-efficient appliances, including: Consumers are more likely to adopt energy-efficient appliances if they perceive them as offering long-term cost savings through reduced energy bills. Increasing awareness of environmental issues and the desire to reduce carbon footprints can motivate consumers to choose energy-efficient appliances. Government incentives, such as rebates, tax credits, and subsidies, can encourage consumers to purchase energy-efficient appliances by reducing their upfront costs.

Clear and informative energy labels help consumers understand the energy efficiency of appliances and make informed purchasing decisions. The availability of a wide range of energy-efficient appliances in the market and their accessibility to consumers can influence adoption rates. Educating consumers about the benefits of energy-efficient appliances and how to identify them can increase adoption rates. Despite the benefits of energy-efficient appliances, several barriers hinder their widespread adoption. These barriers include: Energy-efficient appliances often have a higher upfront cost than standard appliances, which can deter cost-conscious consumers (Damigos, et. al., 2020, de Ayala & Solà, 2022, Hossain, Nekmahmud & Fekete-Farkas, 2022).

Many consumers are unaware of the benefits of energy-efficient appliances or how to identify them, leading to low adoption rates. The availability of energy-efficient appliances varies by market, with some regions having limited access to these products. Some consumers believe that energy-efficient appliances may not perform as well as standard appliances, leading to reluctance to adopt them. Incentives such as rebates and tax credits are not always available or well-publicized, reducing their effectiveness in promoting adoption (Akroush, et. al., 2019, Neves & Oliveira, 2021).

Strategies to overcome these barriers include: Providing financial incentives such as rebates, tax credits, and subsidies can reduce the upfront cost of energy-efficient appliances and incentivize adoption. Educating consumers about the benefits of energy-efficient appliances and how to identify them can increase awareness and adoption rates. Continued innovation in energy-efficient appliance technology can improve performance and reduce costs, making them more attractive to consumers.

Governments can implement regulations that require the use of energy-efficient appliances, driving market demand and adoption. Collaboration between appliance manufacturers, retailers, and policymakers can help create awareness, increase availability, and reduce costs of energy-efficient appliances. In conclusion, understanding the factors influencing consumer adoption of energy-efficient appliances and addressing barriers to their widespread adoption are essential for achieving energy efficiency goals. By implementing strategies to overcome these barriers, policymakers, industry stakeholders, and consumers can work together to promote the adoption of energy-efficient appliances and

reduce energy consumption (Bertoldi, 2022, Singh, Henriques & Martins, 2019, Wohlfarth, Worrell & Eichhammer, 2020).

7 Case Studies and Examples

This section presents case studies and examples of successful implementations of energy-efficient appliances and their real-world impact on household energy consumption and savings. In a residential building in California, a lighting retrofit project was implemented to replace incandescent and CFL bulbs with LED bulbs. The project aimed to improve lighting quality, reduce energy consumption, and lower maintenance costs. After the retrofit, the building's energy consumption for lighting decreased by 60%, resulting in annual savings of $12,000. The project also reduced carbon emissions by 15 tons per year, demonstrating the significant impact of energy-efficient lighting on household energy consumption and savings (Liu, 2020, Powers & Saad, 2022, Witt, et. al., 2019).

A study conducted in Germany evaluated the impact of replacing old refrigerators with energy-efficient models. The study found that households that replaced their old refrigerators with energy-efficient models reduced their energy consumption for refrigeration by up to 50%. This resulted in annual savings of €100 to €150 per household. The study also noted that the new energy-efficient refrigerators had a payback period of 3 to 5 years, making them a cost-effective investment for households (Hueppe, et. al., 2021, Paul, et. al., 2022, Yilmaz, et. al., 2019).

In low-income housing communities in the United States, the installation of energy-efficient appliances has had a significant impact on energy consumption and savings. By replacing old, inefficient appliances with energy-efficient models, households were able to reduce their energy bills by up to 30%. This not only helped lower-income families save money but also contributed to overall energy conservation and reduced carbon emissions.

The adoption of energy-efficient appliances has shown tangible benefits in reducing household energy consumption and saving money. Studies have consistently shown that energy-efficient appliances can reduce energy consumption for various household activities, including heating, cooling, lighting, and refrigeration, by up to 50% (Berkouwer & Dean, 2019, Hafner, et. al., 2019, Iweka, et. al., 2019). Additionally, the long-term savings from energy-efficient appliances outweigh the initial upfront costs, making them a cost-effective investment for households. The widespread adoption of energy-efficient appliances can lead to significant reductions in household energy consumption, resulting in lower utility bills and environmental benefits.

In conclusion, these case studies and examples highlight the real-world impact of energy-efficient appliances on household energy consumption and savings. By promoting the adoption of energy-efficient appliances, policymakers, manufacturers, and consumers can work together to achieve significant energy savings and environmental benefits.

8 Challenges and Limitations

While energy-efficient appliances offer significant benefits in reducing household energy consumption and saving money, there are several challenges and limitations to their widespread adoption and impact. One of the primary challenges of adopting energy-efficient appliances is the upfront costs associated with purchasing these appliances. Energy-efficient appliances tend to be more expensive than their less efficient counterparts, which can deter some consumers, especially those with limited financial resources. The higher upfront costs can create a barrier to adoption, particularly for low-income households, despite the potential long-term savings on energy bills (McAndrew, et. al., 2021, Nguyen, et. al., 2019, Schleich, 2019).

Another challenge is the lack of awareness and education among consumers about the benefits of energy-efficient appliances. Many consumers may not be aware of the potential energy savings and environmental benefits of using energy-efficient appliances. Additionally, there may be misconceptions or lack of understanding about how to choose energy-efficient appliances and interpret energy labels, leading to suboptimal purchasing decisions (Fatoki, 2020, Joshi, Sheorey & Gandhi, 2019, Leary, et. al., 2021).

The availability and variety of energy-efficient appliances in the market can also be a limiting factor. In some regions, energy-efficient appliances may not be readily available, or there may be limited options to choose from. This lack of variety can make it difficult for consumers to find appliances that meet their specific needs and preferences, leading to reluctance in adopting energy-efficient technologies (Camarasa, Kalahasthi & Rosado, 2021, Dolšak, 2023, Hua & Wang, 2019).

To address these challenges, several strategies can be implemented: Governments and utility companies can offer financial incentives, such as rebates or tax credits, to encourage consumers to purchase energy-efficient appliances. These incentives can help offset the higher upfront costs and make energy-efficient appliances more affordable for consumers.

Public awareness campaigns and educational programs can help raise awareness about the benefits of energy-efficient appliances and provide consumers with information on how to choose the right appliances for their needs. These programs can also help dispel misconceptions and improve consumer knowledge about energy efficiency (Blasch, et. al., 2022, Kamaludin, et. al., 2021, Keller, et. al., 2021).

Continued innovation in energy-efficient technologies and increased market development can lead to a greater variety of energy-efficient appliances at competitive prices. This can help expand consumer choices and make energy-efficient appliances more accessible to a wider range of consumers.

In conclusion, while there are challenges and limitations to the widespread adoption of energy-efficient appliances, addressing these challenges through targeted strategies can help unlock the full potential of energy-efficient technologies in reducing household energy consumption and promoting sustainable living.

9 Future Trends and Opportunities

In recent years, the global focus on sustainability and reducing carbon footprints has intensified. One significant area of impact is household energy consumption, which contributes significantly to overall energy usage and greenhouse gas emissions. Energy-efficient appliances have emerged as a key solution to reduce energy consumption in households. This essay explores the future trends and opportunities of reviewing the impact of energy-efficient appliances on household consumption, focusing on technological advancements, policy developments, incentives, and the potential for further reductions in energy consumption (Chien, et. al., 2022, Goldstein, Gounaridis & Newell, 2020, Song, et. al., 2019).

Technological advancements in energy-efficient appliances have been rapid and transformative. Traditional appliances have given way to smart, connected devices that optimize energy usage based on usage patterns, external factors like weather, and real-time energy prices. For example, smart thermostats can learn household schedules and adjust heating and cooling accordingly, leading to significant energy savings. Similarly, energy-efficient lighting solutions, such as LED bulbs, have become mainstream, offering substantial energy savings compared to traditional incandescent bulbs (Grim, et. al., 2020, Kuru & Yetgin, 2019, Wilson, et. al., 2020).

Further advancements are expected in the integration of Artificial Intelligence (AI) and Internet of Things (IoT) technologies in appliances, enabling them to communicate with each other and with external energy management systems. This will enhance the overall efficiency of household energy usage by coordinating appliance operations for maximum energy savings.

Governments worldwide have recognized the importance of promoting energy efficiency in households and have implemented various policies and incentives to encourage the adoption of energy-efficient appliances. These include energy labeling schemes, such as the Energy Star program in the United States, which helps consumers identify and choose energy-efficient products. Additionally, governments offer financial incentives, such as rebates and tax credits, to encourage the purchase of energy-efficient appliances (Ahmad & Zhang, 2021, Mishra & Singh, 2023, Tomazzoli, Scannapieco & Cristani, 2023).

Moreover, some regions have introduced minimum energy performance standards (MEPS) for appliances, ensuring that only energy-efficient products are available in the market. These policies not only promote energy efficiency but also drive innovation among manufacturers to develop more efficient products.

Despite the advancements in energy-efficient appliances and supportive policies, there is still significant potential for further reductions in household energy consumption. This can be achieved through a combination of technological innovation, consumer behavior changes, and policy interventions (Aydin & Brounen, 2019, Spandagos, et. al., 2020, Strielkowski, et. al., 2019).

One area of opportunity is the electrification of appliances currently powered by fossil fuels, such as heating systems and cooking appliances. By transitioning to electric appliances powered by renewable energy sources, households can reduce their carbon footprint significantly.

Additionally, there is potential for further integration of renewable energy sources, such as solar panels and wind turbines, into household energy systems. Energy storage solutions, such as home batteries, can further optimize the use of renewable energy by storing excess energy for later use, reducing reliance on the grid.

Furthermore, consumer education and awareness campaigns can play a crucial role in encouraging energy-efficient practices, such as using appliances during off-peak hours and unplugging devices when not in use.

In conclusion, the future of energy-efficient appliances in reducing household energy consumption is promising, with continuous technological advancements, supportive policies, and opportunities for further reductions in energy usage. By leveraging these trends and opportunities, households can contribute significantly to global efforts to combat climate change and achieve a sustainable future.

10 Conclusion

The review of the impact of energy-efficient appliances on household consumption has highlighted several key findings. Technological advancements have led to the development of smart, connected appliances that optimize energy usage, resulting in significant energy savings. Policy developments and incentives have played a crucial role in promoting the adoption of energy-efficient appliances, but there is still room for further improvements. The potential for further reductions in household energy consumption exists through technological innovation, consumer behavior changes, and policy interventions.

Energy-efficient appliances have the potential to significantly reduce household energy consumption and contribute to sustainability efforts. Technological advancements, such as smart thermostats and energy-efficient lighting, have already demonstrated substantial energy savings. Policy developments, including energy labeling schemes and financial incentives, have encouraged the adoption of energy-efficient appliances.

Policymakers should continue to support the adoption of energy-efficient appliances through effective policies and incentives. This includes setting ambitious energy performance standards, providing financial incentives, and promoting consumer education and awareness.

Manufacturers should prioritize the development of energy-efficient appliances and continue to innovate to improve efficiency further. Collaboration with policymakers and consumers can help drive the market towards more sustainable solutions.

Consumers should consider purchasing energy-efficient appliances and adopt energy-saving practices in their daily lives. Simple actions, such as unplugging devices when not in use and using appliances during off-peak hours, can contribute to significant energy savings.

The future of energy-efficient appliances in household consumption is promising. Continued technological advancements, supportive policies, and consumer awareness can further drive the adoption of energy-efficient appliances. The integration of renewable energy sources and the electrification of appliances powered by fossil fuels offer additional opportunities for reducing household energy consumption. Overall, energy-efficient appliances will continue to play a crucial role in reducing household energy consumption and mitigating climate change. By leveraging the findings and recommendations from this review, stakeholders can work together to create a more sustainable future for all.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Aggarwal, S., & Pathak, S. (2020). Methods of Energy-Saving Measures.

[2] Agyarko, K. A., Opoku, R., & Van Buskirk, R. (2020). Removing barriers and promoting demand-side energy efficiency in households in Sub-Saharan Africa: A case study in Ghana. Energy Policy, 137, 111149.

[3] Ahmad, T., & Zhang, D. (2021). Using the internet of things in smart energy systems and networks. Sustainable Cities and Society, 68, 102783.

[4] Akroush, M. N., Zuriekat, M. I., Al Jabali, H. I., & Asfour, N. A. (2019). Determinants of purchasing intentions of energy-efficient products: The roles of energy awareness and perceived benefits. International Journal of Energy Sector Management, 13(1), 128-148.

[5] Aliero, M. S., Qureshi, K. N., Pasha, M. F., & Jeon, G. (2021). Smart Home Energy Management Systems in Internet of Things networks for green cities demands and services. Environmental Technology & Innovation, 22, 101443.

[6] Aydin, E., & Brounen, D. (2019). The impact of policy on residential energy consumption. Energy, 169, 115-129.

[7] Bastida, L., Cohen, J. J., Kollmann, A., Moya, A., & Reichl, J. (2019). Exploring the role of ICT on household behavioural energy efficiency to mitigate global warming. Renewable and Sustainable Energy Reviews, 103, 455-462.

[8] Berkouwer, S. B., & Dean, J. T. (2019). Credit and attention in the adoption of profitable energy efficient technologies in Kenya.

[9] Bertoldi, P. (2022). Policies for energy conservation and sufficiency: Review of existing policies and recommendations for new and effective policies in OECD countries. Energy and Buildings, 264, 112075.

[10] Bhutto, M. Y., Liu, X., Soomro, Y. A., Ertz, M., & Baeshen, Y. (2020). Adoption of energy-efficient home appliances: Extending the theory of planned behavior. Sustainability, 13(1), 250.

[11] Blasch, J. E., Filippini, M., Kumar, N., & Martinez-Cruz, A. L. (2022). Boosting the choice of energy-efficient home appliances: the effectiveness of two types of decision support. Applied Economics, 54(31), 3598-3620.

[12] Brockway, P. E., Sorrell, S., Semieniuk, G., Heun, M. K., & Court, V. (2021). Energy efficiency and economy-wide rebound effects: A review of the evidence and its implications. Renewable and sustainable energy reviews, 141, 110781.

[13] Callebaut, G., Leenders, G., Van Mulders, J., Ottoy, G., De Strycker, L., & Van der Perre, L. (2021). The art of designing remote iot devices—technologies and strategies for a long battery life. Sensors, 21(3), 913.

[14] Camarasa, C., Kalahasthi, L. K., & Rosado, L. (2021). Drivers and barriers to energy-efficient technologies (EETs) in EU residential buildings. Energy and Built Environment, 2(3), 290-301.

[15] Chen, S., Zhang, G., Xia, X., Setunge, S., & Shi, L. (2020). A review of internal and external influencing factors on energy efficiency design of buildings. Energy and Buildings, 216, 109944.

[16] Chien, F., Hsu, C. C., Ozturk, I., Sharif, A., & Sadiq, M. (2022). The role of renewable energy and urbanization towards greenhouse gas emission in top Asian countries: Evidence from advance panel estimations. Renewable Energy, 186, 207-216.

[17] Cristino, T. M., Neto, A. F., Wurtz, F., & Delinchant, B. (2021). Barriers to the adoption of energy-efficient technologies in the building sector: A survey of Brazil. Energy and Buildings, 252, 111452.

[18] Damigos, D., Kontogianni, A., Tourkolias, C., & Skourtos, M. (2020). Behind the scenes: Why are energy efficient home appliances such a hard sell?. Resources, Conservation and Recycling, 158, 104761.

[19] de Ayala, A., & Solà, M. D. M. (2022). Assessing the EU Energy Efficiency Label for Appliances: Issues, Potential Improvements and Challenges. Energies, 15(12), 4272.

[20] De Ayala, A., Foudi, S., Solà, M. D. M., López-Bernabé, E., & Galarraga, I. (2021). Consumers' preferences regarding energy efficiency: a qualitative analysis based on the household and services sectors in Spain. Energy Efficiency, 14(1), 3.

[21] Dinh, H. T., & Kim, D. (2021). An optimal energy-saving home energy management supporting user comfort and electricity selling with different prices. IEEE Access, 9, 9235-9249.

[22] Dolšak, J. (2023). Determinants of energy efficient retrofits in residential sector: A comprehensive analysis. Energy and Buildings, 282, 112801.

[23] Enteria, N., Cuartero-Enteria, O., & Sawachi, T. (2020). Review of the advances and applications of variable refrigerant flow heating, ventilating, and air-conditioning systems for improving indoor thermal comfort and air quality. International Journal of Energy and Environmental Engineering, 11(4), 459-483.

[24] Fatoki, O. (2020). Factors influencing the purchase of energy-efficient appliances by young consumers in South Africa. Foundations of Management, 12(1), 151-166.

[25] Giraudet, L. G. (2020). Energy efficiency as a credence good: A review of informational barriers to energy savings in the building sector. Energy Economics, 87, 104698.

[26] Goldstein, B., Gounaridis, D., & Newell, J. P. (2020). The carbon footprint of household energy use in the United States. Proceedings of the National Academy of Sciences, 117(32), 19122-19130.

[27] Grim, R. G., Huang, Z., Guarnieri, M. T., Ferrell, J. R., Tao, L., & Schaidle, J. A. (2020). Transforming the carbon economy: challenges and opportunities in the convergence of low-cost electricity and reductive CO 2 utilization. Energy & Environmental Science, 13(2), 472-494.

[28] Grondzik, W. T., & Kwok, A. G. (2019). Mechanical and electrical equipment for buildings. John wiley & sons.

[29] Hafner, R., Elmes, D., Read, D., & White, M. P. (2019). Exploring the role of normative, financial and environmental information in promoting uptake of energy efficient technologies. Journal of Environmental Psychology, 63, 26-35.

[30] Hesselink, L. X., & Chappin, E. J. (2019). Adoption of energy efficient technologies by households–Barriers, policies and agent-based modelling studies. Renewable and Sustainable Energy Reviews, 99, 29-41.

[31] Hossain, I., Nekmahmud, M., & Fekete-Farkas, M. (2022). How do environmental knowledge, eco-label knowledge, and green trust impact consumers' pro-environmental behaviour for energy-efficient household appliances?. Sustainability, 14(11), 6513.

[32] Hua, L., & Wang, S. (2019). Antecedents of consumers' intention to purchase energy-efficient appliances: An empirical study based on the technology acceptance model and theory of planned behavior. Sustainability, 11(10), 2994.

[33] Hueppe, C., Geppert, J., Moenninghoff-Juessen, J., Wolff, L., Stamminger, R., Paul, A., ... & Freiberger, A. (2021). Investigating the real life energy consumption of refrigeration appliances in Germany: Are present policies sufficient?. Energy Policy, 155, 112275.

[34] Islam, R., Haque, R., & Mahmud, M. (2021). Intelligent Energy Efficient Embedded Home Automation System (Doctoral dissertation, Department of Electrical and Electronic Engineering, Islamic University of Technology (IUT), Board Bazar, Gazipur-1704, Bangladesh).

[35] Iweka, O., Liu, S., Shukla, A., & Yan, D. (2019). Energy and behaviour at home: A review of intervention methods and practices. Energy Research & Social Science, 57, 101238.

[36] Javid, M., & Khan, M. (2020). Energy efficiency and underlying carbon emission trends. Environmental Science and Pollution Research, 27(3), 3224-3236.

[37] Joshi, G. Y., Sheorey, P. A., & Gandhi, A. V. (2019). Analyzing the barriers to purchase intentions of energy efficient appliances from consumer perspective. Benchmarking: An International Journal, 26(5), 1565-1580.

[38] Joshi, G. Y., Sheorey, P. A., & Gandhi, A. V. (2019). Analyzing the barriers to purchase intentions of energy efficient appliances from consumer perspective. Benchmarking: An International Journal, 26(5), 1565-1580.

[39] Kamaludin, M., Razali, M. A. S., Haron, N. F., & Aziz, A. A. (2021). Energy efficiency labelling: investigating students' preferences and awareness on the energy-efficient electrical appliances in hostel. International Journal of Energy Economics and Policy, 11(2), 300-308.

[40] Keller, S., Otjen, A. J., McNally, M., Wilkinson, T. J., Dockery, B., Leonard, J., & Southworth, H. (2021). Improving awareness of energy conservation: Rocky Mountain City. Journal of Ethics in Entrepreneurship and Technology, 1(1), 4-19.

[41] Kuru, K., & Yetgin, H. (2019). Transformation to advanced mechatronics systems within new industrial revolution: A novel framework in automation of everything (AoE). IEEE Access, 7, 41395-41415.

[42] Lackner, M. (2022). Energy efficiency: Comparison of different systems and technologies. In Handbook of climate change mitigation and adaptation (pp. 381-456). Cham: Springer International Publishing.

[43] Leary, J., Menyeh, B., Chapungu, V., & Troncoso, K. (2021). ECooking: Challenges and opportunities from a consumer behaviour perspective. Energies, 14(14), 4345.

[44] Li, G., Li, W., Jin, Z., & Wang, Z. (2019). Influence of environmental concern and knowledge on households' willingness to purchase energy-efficient appliances: A case study in Shanxi, China. Sustainability, 11(4), 1073.

[45] Liao, X., Shen, S. V., & Shi, X. (2020). The effects of behavioral intention on the choice to purchase energy-saving appliances in China: the role of environmental attitude, concern, and perceived psychological benefits in shaping intention. Energy Efficiency, 13(1), 33-49.

[46] Liu, L. (2020). Improving Building Sustainability: Lighting Life Cycle Optimization and Management, and HVAC Demand Response (Doctoral dissertation).

[47] Lun, Y. V., & Tung, S. D. (2019). Heat pumps for sustainable heating and cooling. Springer Nature.

[48] Mathias, J. A., Juenger, K. M., & Horton, J. J. (2023). Advances in the energy efficiency of residential appliances in the US: A review. Energy Efficiency, 16(5), 1-21.

[49] McAndrew, R., Mulcahy, R., Gordon, R., & Russell-Bennett, R. (2021). Household energy efficiency interventions: A systematic literature review. Energy Policy, 150, 112136.

[50] McGinley, O., Moran, P., & Goggins, J. (2022). An Assessment of the Key Performance Indicators (KPIs) of Energy Efficient Retrofits to Existing Residential Buildings. Energies, 15(1), 334.

[51] Mehmood, M. U., Chun, D., Han, H., Jeon, G., & Chen, K. (2019). A review of the applications of artificial intelligence and big data to buildings for energy-efficiency and a comfortable indoor living environment. Energy and Buildings, 202, 109383.

[52] Mishra, P., & Singh, G. (2023). Energy management systems in sustainable smart cities based on the internet of energy: A technical review. Energies, 16(19), 6903.

[53] Neves, C., & Oliveira, T. (2021). Drivers of consumers' change to an energy-efficient heating appliance (EEHA) in households: Evidence from five European countries. Applied Energy, 298, 117165.

[54] Neves, J., & Oliveira, T. (2021). Understanding energy-efficient heating appliance behavior change: The moderating impact of the green self-identity. Energy, 225, 120169.

[55] Nguyen, N., Greenland, S., Lobo, A., & Nguyen, H. V. (2019). Demographics of sustainable technology consumption in an emerging market: The significance of education to energy efficient appliance adoption. Social Responsibility Journal, 15(6), 803-818.

[56] Okoye, C. U., & Adelakun, N. O. (2019). Design and Evaluation of Electrical Services for an Energy Efficient Home. Iconic Research and Engineering Journals, 3(6), 95-102.

[57] Paramati, S. R., Shahzad, U., & Doğan, B. (2022). The role of environmental technology for energy demand and energy efficiency: Evidence from OECD countries. Renewable and Sustainable Energy Reviews, 153, 111735.

[58] Paul, A., Baumhögger, E., Elsner, A., Reineke, M., Hueppe, C., Stamminger, R., ... & Vrabec, J. (2022). Impact of aging on the energy efficiency of household refrigerating appliances. Applied Thermal Engineering, 205, 117992.

[59] Powers, A., & Saad, M. (2022). Building Energy Use: Modeling and Analysis of Lighting Systems—A Case Study. Sustainability, 14(20), 13181.

[60] Schleich, J. (2019). Energy efficient technology adoption in low-income households in the European Union–What is the evidence?. Energy Policy, 125, 196-206.

[61] Shah, N., Park, W. Y., & Ding, C. (2021). Trends in best-in-class energy-efficient technologies for room air conditioners. Energy Reports, 7, 3162-3170.

[62] Singh, V. K., Henriques, C. O., & Martins, A. G. (2019). Assessment of energy-efficient appliances: A review of the technologies and policies in India's residential sector. Wiley Interdisciplinary Reviews: Energy and Environment, 8(3), e330.

[63] Solà, M. D. M., de Ayala, A., Galarraga, I., & Escapa, M. (2021). Promoting energy efficiency at household level: a literature review. Energy Efficiency, 14, 1-22.

[64] Song, K., Qu, S., Taiebat, M., Liang, S., & Xu, M. (2019). Scale, distribution and variations of global greenhouse gas emissions driven by US households. Environment international, 133, 105137.

[65] Spandagos, C., Yarime, M., Baark, E., & Ng, T. L. (2020). "Triple Target" policy framework to influence household energy behavior: Satisfy, strengthen, include. Applied Energy, 269, 115117.

[66] Strielkowski, W., Volkova, E., Pushkareva, L., & Streimikiene, D. (2019). Innovative policies for energy efficiency and the use of renewables in households. Energies, 12(7), 1392.

[67] Šujanová, P., Rychtáriková, M., Sotto Mayor, T., & Hyder, A. (2019). A healthy, energy-efficient and comfortable indoor environment, a review. Energies, 12(8), 1414.

[68] Tomazzoli, C., Scannapieco, S., & Cristani, M. (2023). Internet of things and artificial intelligence enable energy efficiency. Journal of Ambient Intelligence and Humanized Computing, 14(5), 4933-4954.

[69] Verma, P., Kumari, T., & Raghubanshi, A. S. (2021). Energy emissions, consumption and impact of urban households: A review. Renewable and Sustainable Energy Reviews, 147, 111210.

[70] Wang, B., Deng, N., Liu, X., Sun, Q., & Wang, Z. (2021). Effect of energy efficiency labels on household appliance choice in China: Sustainable consumption or irrational intertemporal choice?. Resources, Conservation and Recycling, 169, 105458.

[71] Wang, Y., Wang, J., & He, W. (2022). Development of efficient, flexible and affordable heat pumps for supporting heat and power decarbonisation in the UK and beyond: Review and perspectives. Renewable and Sustainable Energy Reviews, 154, 111747.

[72] Wang, Z., Sun, Q., Wang, B., & Zhang, B. (2019). Purchasing intentions of Chinese consumers on energy-efficient appliances: Is the energy efficiency label effective?. Journal of Cleaner Production, 238, 117896.

[73] Waris, I., & Hameed, I. (2020). Promoting environmentally sustainable consumption behavior: an empirical evaluation of purchase intention of energy-efficient appliances. Energy Efficiency, 13(8), 1653-1664.

[74] Wilson, C., Grubler, A., Bento, N., Healey, S., De Stercke, S., & Zimm, C. (2020). Granular technologies to accelerate decarbonization. Science, 368(6486), 36-39.

[75] Witt, S. M., Stults, S., Rieves, E., Emerson, K., & Mendoza, D. L. (2019). Findings from a pilot light-emitting diode (LED) bulb exchange program at a neighborhood scale. Sustainability, 11(14), 3965.

[76] Wohlfarth, K., Worrell, E., & Eichhammer, W. (2020). Energy efficiency and demand response–two sides of the same coin?. Energy Policy, 137, 111070.

[77] Xiao, H., Yang, Z., Shi, W., Wang, B., Li, B., Song, Q., ... & Xu, Z. (2022). Comparative analysis of the energy efficiency of air-conditioner and variable refrigerant flow systems in residential buildings in the Yangtze River region. Journal of Building Engineering, 55, 104644.

[78] Yilmaz, S., Majcen, D., Heidari, M., Mahmoodi, J., Brosch, T., & Patel, M. K. (2019). Analysis of the impact of energy efficiency labelling and potential changes on electricity demand reduction of white goods using a stock model: The case of Switzerland. Applied Energy, 239, 117-132.

[79] Zhang, Y., Xiao, C., & Zhou, G. (2020). Willingness to pay a price premium for energy-saving appliances: Role of perceived value and energy efficiency labeling. Journal of Cleaner Production, 242, 118555.

[80] Zou, B., & Mishra, A. K. (2020). Appliance usage and choice of energy-efficient appliances: Evidence from rural Chinese households. Energy Policy, 146, 111800.