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A Systematic Review of Energy Demand, Technology, and Efficiency Nexus: Implications for Bangladeshi Food Processing Industry

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ABSTRACT

Designing energy efficiency strategies for industries is predicted to be challenging. Energy is not always efficiently utilized in energy-intensive industries due to various issues, notably technology and equipment. Therefore, through a systematic review, this study aims to investigate the relationship between energy demand, technological breakthroughs, and efficiencies, with implications for the food processing industry of Bangladesh. The study utilizes the Scopus database to perform a systematic evidence search, screening, and finally selection of articles for literature review between the years 2010 and 2022. From a total of 1253 initially searched articles, 10 were selected for final review. According to the reviewed literature, energy demand in the food processing industry is expected to surge in the future, which is influenced by various factors. To tackle the challenges, deploying energy-saving technologies could be a strategy for energy conservation, enhancing efficiency and strengthening organizational growth, profitability and sustainability.

INTRODUCTION

Energy is a crucial component in any economic activity, and increased energy demand signals economic progress if there is no indication of energy inefficiency (Anik & Rahman, 2021). Global energy demand has doubled in the previous five and a half decades (Kibria, Akhundjanov, & Oladi, 2019). Bangladesh, often acclaimed as one of the world's fastest-growing economies, experiences a rising energy demand which has already become a matter of concern due to limited supply and sources (Murshed, 2021). Total energy consumption in Bangladesh has experienced a sharp increase from 0.12 quad Btu in 1980 to 1.835 quad Btu in 2020 (EIA, 2020). This demand is likely to rise even faster in the near future because of the rapid rate of urbanization and industrialization (Anik & Rahman, 2021).

On the other hand, due to large-scale production and high nutritional benefits, the establishment of food processing enterprises is strengthened, which boosts farmers' economic condition (Sanusi, Ashaolu, Akogun, & Ayinde, 2016). South Asian countries like Bangladesh enjoy a strategic advantage in the food processing industry as it relies on its adequate agricultural inputs (World Bank, 2012). However, the perishability and seasonality feature of agricultural raw materials makes the activities of the agro-food processing industry challenging (Nwakuba, Ndukwe, & Paul, 2021). In any type of food processing industry, energy is generally needed for machinery, technological devices, and equipment handling operations such as freezing, drying, heating, refrigeration and cooling (Murali, Krishnan, Amulya, Alfiya, Delfiya, & Samuel, 2021). It is crucial to determine the scope for minimizing energy demand in the food processing industry and enhancing efficiency by properly utilizing technologies. Bangladesh is gradually reassigning from petroleum to natural gas sources which are depleting fast to meet the energy demand of different sectors like the food processing sector (Anik & Rahman, 2021). Besides, the demand for food is increasing gradually as the population rises, resulting in massive pressure on energy consumption (Bajan, Mrówczy´nska-Kami´nska & Poczta, 2020).

Energy efficiency is ensured when the same amount of output requires comparatively less energy consumption in the production plant (Gembicki, 2016). More precisely, efficiency is primarily the association between the input and output parameters. Through efficiency measurement, the performance and quality of transforming input into output can be assessed (Lu, Chiu, Chiu, & Chang, 2022). Despite advancements in different areas, the food processing industry faces enormous hurdles of high energy consumption and low operational efficiency (Nwakuba *et al.*, 2021). In this case, technological innovation is one of the leading measures to shrink energy consumption, confirming energy efficiency (Sohag, Begum, Abdullah & Jaafar, 2015). Hence, achieving energy efficiency is a must for the country to survive in the long run (Gembicki, 2016). Considering the significance, this study aims to review the possibilities of ensuring energy efficiency through technological innovation in the food processing industry of Bangladesh. This article depicts the research background followed by the methodology, literature review, findings and discussion section. It ends with implications and contributions to this area of study.

Background of the Study

Food processing is one of the world's largest and growing industries (Ahmadi, Das, Ehyaei, Esmaeilion, Assad, Jamali, Koohshekan, Kumar, Rosen, Negi, Bhogilla, & Safari, 2021). It has become the mainstay of the country's viable long-run social and economic growth. From Bangladesh's perspective, over 700 raw and processed

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food products are exported to over 140 countries, generating US$400 million, employing approximately 40% of the labor force directly and indirectly and contributing 16% to the country's GDP (BIDA, 2020). This industry eases poverty, increases the standard of living, creates employment opportunities, generates export earnings and boosts the country's overall growth and development. Therefore, the food processing industry has huge potential to unlock and accelerate economic growth, and strengthen the growth and advancement of a developing nation like Bangladesh.

In a similar fashion, energy is considered one of the basic factors of production contributing to the GDP of any economy (Lee & Change, 2008). Furthermore, it is sometimes termed as the economy's lifeblood as it directly influences different macroeconomic variables (Azam, 2020). Energy, especially electricity, is an indispensable factor for Bangladesh's economic advancement as the country's swift economic progression in the near future will require more electricity supply (Mondal, Boie, & Denich, 2010). In 2019, Bangladesh is ranked 47th in terms of total energy usage, with an upward demand trend (EIA, 2020). Moreover, energy demand is rising despite limited supplies and sources; thus, exploring the dynamics of energy consumption and achieving energy efficiency for the future is crucial (Murshed & Alam, 2021).

In particular, the food processing industry requires huge energy to perform its day-to-day operations (Ahmadi *et al.*, 2021). This sector comprises energy-intensive operations, and incurs expenses, accounting for 20 to 50 percent of total production costs (Clairand, Briceño-León, Escrivá-Escrivá, & Pantaleo, 2020). Similarly, in this era of technological advancements, like all others, the energy sector is also trying to employ sophisticated and innovative technology to achieve energy efficiency (Chen, Sinha, Hu & Shah, 2021). Relevantly, scholarly attention has been drawn recently to the advent of energy-saving, alternative technologies.

The energy demand, technology, and efficiency nexus in Bangladesh's food processing industry is gaining traction and necessitates exploring numerous undiscovered concerns. Many studies explore energy demand, technology and efficiency as separate topics. However, the studies combining energy demand, technology and efficiency relationships, to leave directions for the food processing industry of Bangladesh are hardly found in the extant literature. Hence, scholarly attention is required to close this identified research gap and address a major research question (i) does the installation of energy-saving technology impact the achievement of efficiency in energy consumption of the food processing industry in Bangladesh? Therefore, this study aims to conduct a systematic review to reveal the impact of energy-efficient technology on energy demand management in the food processing industry, with a specific reference to Bangladesh.

LITERATURE REVIEW

Estimating the macroeconomic determinants of Bangladesh's total, renewable, and non-renewable energy demands: the role of technological innovations (Murshed & Alam, 2021). Murshed and Alam (2021) work on the overall energy demand for both primary energy and electricity consumption in Bangladesh from 1980–2014, aiming to explore the influencing factors by employing econometric analysis tools. The study shows that economic advancements and increased household consumption upturn energy demand whereas income inequality produces the opposite result. The study also found that technological innovation demotivates total and non-renewable energy demand while motivating renewable energy demand. Besides, the increased oil price does not affect renewable energy demand but slows down non-renewable energy demand.

The nexuses between energy investments, technological innovations, emission taxes, and carbon emissions in China (Ma, Murshed, & Khan, 2021). Ma, Murshed, & Khan (2021) investigate the carbon emissions and the related issues in the provincial area of China considering the sample period from 1995 to 2019 by employing sophisticated econometric analysis. The study reveals that economic growth in the provinces and development in the tertiary sector are the major causes of excessive energy consumption, leading to carbon emissions in China. On the contrary, technological innovation, renewable energy, research and development investment, and emission taxes can reduce carbon emissions and demotivate fossil fuel use.

Economic Energy Efficiency of Food Production Systems (Bajan, Mrówczy´nska-Kami´nska, & Poczta, 2020). Bajan *et al* (2020) address the traditional problem of increasing energy consumption due to population growth over time. They undertake a research initiative that aims to analyze the economic energy efficiency in the case of food production in the cross-country context. The study illustrates that the energy consumption of food production increased by around 27% in the selected countries from the period of 2000 to 2014. But surprisingly, energy intensity is decreased by around 18%, meaning achieving energy efficiency is possible even if the energy consumption increases. To execute the study, the researchers use the World Input-Output Database (WIOD) as the source of data and the Economic Input-Output Life Cycle Assessment (EIO-LCA) was employed as analysis method. The research is limited by the fact that farming conditions vary between nations.

Machine Learning Methods in Energy Consumption Optimization Assessment in Food Processing Industry (Milczarski, Stawska, Hłobaż, Zieliński, Maślanka, & Kosiński, 2021). Milczarski, Stawska, Hłobaż, Zieliński, Maślanka, and Kosiński (2021) in their study demonstrate the process of carbon footprint optimization to ensure the products contain comparatively low carbon. In this study

funded by the Polish R&D Agency under the CFOOD project, they employ LCA (Life Cycle Assessment) model to analyze and represent the carbon footprint. Furthermore, they apply the clusterization method to better discuss the carbon footprint of frozen vegetables. The researchers employ three types of clusterization namely K-means clusterization, EM clusterization and Canopy clusterization.

A review on boilers energy use, energy savings, and emissions reductions (Barma, Saidur, Rahman, Allouhi, Akash & Sait, 2017). Barma, Saidur, Rahman, Allouhi, Akash, and Sait (2017) conduct a study on the boiler's efficiency so that the consumption of fossil fuel can be reduced and CO_2 emissions can also be regulated. To reach the solution, they go through an extensive literature review and illustrate the reasons and remedies. According to the study, 70 to 90% of energy is utilized in a typical boiler, whereas 10 to 30% of energy is lost as heat. Hence, optimizing boiler efficiency by limiting heat loss can significantly reduce fossil fuel usage, hence improving energy efficiency. Major causes for heat loss are found as flue gas may be due to leaks, radiation and blowing down. The study suggests some remedial measures to the energy losses like controlling the excessive air, different heat recovery techniques and performing efficient energy audits and maintenance activities. Besides, the study focuses on creating awareness among the staffs involved by providing education, training and seminar programs.

Table 1: Summary of Reviewed Literature

Author (s) & Year	Subjects & Contexts	Key Findings	Estimation Methods	Future Research Direction
Murshed & Alam, 2021	Macroeconomic determinants of energy demand Bangladesh	Economic advancement increases the energy demand. Technological innovation declines the total and non-renewable energy and upsurges the renewable energy demand.	Econometric methods Co integration Unit root test ARDL	Further research initiatives should be undertaken to explore more macroeconomic variables influencing the energy sector of Bangladesh.
Ma, Murshed & Khan, 2021	Energy investments & Technological innovation China	Economic growth in the provinces and tertiary development increase energy use as well as carbon emissions. Technological innovation, increased use of renewable energy, investment in research and development, and imposing emission taxes can reduce carbon emissions.	Econometric Analysisw	Transportation, a major sector can be considered in the case of Carbon emission and a non-linear modeling approach can be used in future studies.
Bajan, Mrówczy´nska-Kami´nska & Poczta, 2020	Energy efficiency in food production sector 14 selected countries	Achieving energy efficiency is possible even the energy consumption increases.	EIO-LCA	-
Milczarski *et al.*, 2021	Energy optimization in the food processing industry Poland	The study revealed carbon footprint optimization techniques ensure low carbon in food. Though the minimum energy consumption in the production stage of life cycle assessment (LCA) is enticing, it leads to increased energy intake in the cold-store or products destruction stage owing to poor manufacturing technology	The life cycle assessment (LCA) model	-

Barma *et al.*, 2017	Energy saving and emission reduction technology	Fossil fuel consumption can be decreased by increasing the boiler's efficiency through preventing wastage heat, proper maintenance, training and education, etc.	-	The heat recovery techniques need to be further examined by future research initiatives.
Chen, Sinha, Hu & Shah, 2021	Technological innovation and energy efficiency Middle East and North African (MENA) countries	Technological innovation and reformation of economic structure ensure energy efficiency. Economic growth decreases energy efficiency.	Unit root test Chudik and Pesaran (2015) cross-sectional dependence test Cross-sectional augmented Dickey-Fuller (CADF) test Cross-sectional Im-Pesaran-Shin (CIPS) test	The influence of bi-lateral trade, dispersion of innovation and its nature should be investigated in further study.
Ouyang, Jian, & Jiang, 2022	Energy efficiency in industries China	Achieving energy efficiency is essentially required for energy conservation and ecological preservation. Regional technology differences limit energy efficiency. Planned industrial expansion and innovation can ensure energy efficiency.	Parametric meta-frontier analysis	-
Sohag, Begum, Abdullah & Jaafar, 2015	Dynamics of energy use Malaysia	Technological innovation is found as a vital factor in reducing energy use. Economic growth and trade openness are liable for triggering energy use.	ARDL DOLS Gregory Hansen	-
Bölük & Koç, 2010	The electricity demand of the manufacturing sector Turkey	Demand for electricity is sensitive to price change. Electricity, labor and capital are corresponding with each other. Labor and capital demand are influenced by electricity price changes. Intermediate input was found more inelastic.	Translog Cost Function Framework	-
Islam, 2021	Dynamics of energy use Bangladesh	GDP per capita and trade openness are responsible for increasing energy use. Technological innovation ensures energy efficiency.	ARDL	-

However, the suggested heat recovery techniques needed to be further examined for improved results.

Impact of technological innovation on energy efficiency in industry 4.0 era: Moderation of shadow economy in sustainable development (Chen, Sinha, Hu & Shah, 2021). Chen *et al* (2021) studied MENA countries from 1990–2016 using a second-generation methodology in the Industry 4.0 and Sustainable Development Goals (SDGs) contexts. This study highlights how energy demand is associated with technological innovation, the shadow economy, and structural transformation to help MENA countries achieve the SDGs. The findings reveal that technological innovation and economic structure reform improve energy efficiency when economic growth interferes. Based on the results, they have devised an SDG framework that could aid MENA states in achieving SDGs 7, 8, 9, and 4.

Energy efficiency of the industrial sectors in Beijing-Tianjin-Hebei urban agglomeration: does technological gap matter (Ouyang, Jian, & Jiang, 2022). Ouyang, Jian, and Jiang (2022) in their study use Parametric meta-frontier analysis to determine the industrial total-factor energy efficiency (TFEE) of the Beijing Tianjin Hebei urban agglomeration (BTHUA), focusing on the regional technology gap ratio (TGR) based on data between 2005-2018. This study, funded by the National Natural Science Foundation of China, claimed that energy efficiency is crucial to energy conservation and ecological preservation, which help achieve sustainable economic reforms. The findings show that BTHUA's industrial TFEE is geographically unequal. Beijing has the region's highest TGRs. In this manner, regional technology differences limit energy efficiency. Nonetheless, the region has the opportunity to preserve energy and reduce emissions through planned industrial expansion and advancements in energy efficiency.

Dynamics of energy use, technological innovation, economic growth and trade openness in Malaysia (Sohag, Begum, Abdullah & Jaafar, 2015). Sohag *et al* (2015) conducted a study to assess the impact of technological innovation on the efficient use of energy considering the effect in terms of economic growth and trade openness by analyzing the secondary data available in the sample period 1985-2012 in Malaysia. The study demonstrates that technological innovation has a positive impact on reducing energy use since it warrants more energy efficiency. On the other side, economic growth and trade openness are found substantial variables to trigger the energy use in Malaysia during the sample period. To execute the analysis, the ARDL (Auto-Regressive Distributed Lag), the DOLS (Dynamic Ordinary Least Squares) and Gregory-Hansen estimation tools were employed. The study has a limitation in that CO_2 emissions were not considered as a variable.

Electricity demand of manufacturing sector in Turkey: A translog cost approach (Bölük & Koç, 2010). Bölük and Koç (2010) in their empirical study considering four variables- Capital, Labour, Intermediate Input and Electricity, illustrate that electricity demand is sensitive to price change where electricity, labor and capital all are correlated. The study furthermore explores that the labor and capital demand are highly influenced by the changes in electricity price where the intermediate input was found more inelastic. The study was conducted by investigating the secondary data available for the period between 1980 and 2001 in the Turkey context by employing Translog Cost Function Framework.

Dynamics of energy use, technological innovation, economic growth, and trade openness in Bangladesh (Islam, 2021). Islam (2021) has tried to examine the relationship between technological innovations and energy usage, with a particular reference to Bangladesh. The author utilizes Marshallian demand function as the study backdrop. The data from a total of 37 years (1980-2016) has been sampled for analysis employing ARDL (autoregressive distributed lag) bounds testing approach. The empirical findings reveal that GDP per capita and trade openness are the key determinants of increased energy consumption. The study also results that technological innovation directs to an increase in energy efficiency and reduces its consumption in Bangladesh. The study recommends Bangladesh replace old, energy-inefficient systems with innovative, energy-efficient technology to achieve sustainable energy security.

METHODOLOGY

Beginning with the central research gap, a systematic literature review is carried out to portray the extant literature on the energy demand scenario in relation to technology and energy efficiency. The research question has been arranged, structured and categorized considering the population- intervention- exposure- comparator-outcome (PIECO) elements.

Population (s): Food processing industry and Bangladesh. Intervention (s): Installation of energy-saving technology in the industry. Exposure (s): Energy-efficient food processing plants. Comparator(s): energy consumption before and after utilizing energy-saving technology. Outcome (s): Level of efficiency achieved in energy consumption in the industry after the installation of energy-saving technology. Based on PIECO elements, the relevant literature has been searched, screened and reviewed to update the present state of knowledge and provide exemplary research directions.

Searching the literature

Database for Literature Search

A systematic literature review is dependent on the sources of literature and the process in which they are searched (Xiao & Watson, 2019). In this case, a systematic literature search is conducted using the Scopus database, followed by title, abstract, full-text screening and final inclusion. Scopus is used to search the literature because it covers a huge number of journals (Paul & Criado, 2020). Besides, it is easier to obtain a search result from the Scopus database and download it directly in.csv format (Roy, Some, Das, & Pathak, 2021).

Keywords Utilized for the Search

The search keywords have been derived from the formulated research question, which is further divided into concept domains using the PIECO elements. Synonyms, acronyms, alternate spellings, and similar phrases are also used, which can broaden the notions in the search queries (Rowley & Slack, 2004). To include and join the main terms and synonyms, the search string is built using the Boolean operators "AND" and "OR". Two search queries (search query 1 and search query 2) have been constructed and utilized for searching the literature from the Scopus database.

Search Query 1

("energy demand" OR "energy demand modelling" OR "electricity model" OR "electricity modelling" OR "electricity demand model" OR "electricity demand modelling" OR "industrial electricity demand" OR "electricity demand estimate" OR "electricity usage" OR "electricity consumption" OR "electricity demand forecasting" OR "energy efficiency" OR "energy sustainability" OR "environment sustainability" OR "electricity sustainability" OR "electricity efficiency" OR "electricity saving technology" OR "energy saving technology" OR "energy efficient equipment" OR "energy efficient technology" OR "energy efficient machinery") AND ("food manufacturing industry" OR "food processing industry" OR "food supply chain" OR "beverage processing industry" OR " fruit processing industry" OR "agro-based industry" OR agribusiness) AND (bangladesh OR asia OR "developing countries")

Search Query 2

"electricity demand modelling" OR "electricity demand" OR "price elasticity for electricity" OR "demand elasticity for electricity" OR "income elasticity for electricity" OR "cross price elasticity" AND "electricity efficient technology" OR "technological innovation" AND bangladesh OR asia

Identification of Literature

Two search queries, based on PIECO elements, specified in annexes A and B are employed to identify articles from Scopus, yielding 1054 articles from search query 01 and 199 from search query 02, for a total of 1253 articles. The literature search was done with the utmost care and caution to avoid common errors.

Screening and Final Inclusion

After compiling a list of articles, screening is crucial to determine whether the articles are to be included for review (Xiao, Y., & Watson, M. (2019). The screening procedure begins with title screening, continues with abstract screening, and concludes with full-text screening. This study screens 78 of 1253 articles by title, 22 by abstract and 10 by full-text read review. This full-text reviewed 10 articles have been chosen for final review. It comprises articles from diverse settings and perspectives from the Scopus database, to be included for final review. This process limits and covers the documents from 2010 to 2022.

Table 2: Articles inclusion criteria for review at different phases

Phases	Inclusion (No. of articles included)
Phase 1: Identifying the articles	
The search queries 01 and 02 are employed to identify articles from Scopus	1253
Phase 2: Eligibility criteria to be included	
Following the title screening	78
Following abstract screening	22
After full text review	10
Phase 3: Finally included articles	
Total articles included for the study	10

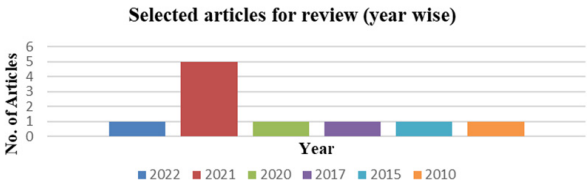

Figure 1: Year wise number of articles selected for final review (2010-2022)

Table 3: Type and ranking of 10 papers, selected for review

Type of Paper	Number	Scimago Journal Rank
Journal Article	9	Q1 = 8 Q3 = 1
Conference Paper	1	-----

RESULTS AND DISCUSSIONS

Economic expansion and higher household energy consumption increase the aggregate energy demand in Bangladesh (Murshed & Alam, 2021). Since this demand will continue to increase, addressing the energy demand-supply imbalance would be a government priority. Generally, economic growth and development at the tertiary level are leading motives for energy consumption, whereas factors like technological innovation, spending

on research and development, relying more on renewable energy, emission taxes, etc. are conducive to reduced energy consumption, thus releasing less carbon (Ma *et al.*, 2021). Like in other developing economies, the growing population is one of Bangladesh's largest drivers of energy demand. Though population growth increases energy consumption, energy-efficient food production lowers energy demand (Bajan *et al.*, 2020).

In particular, each phase of food processing necessitates a significant amount of energy intake. However, energy use can be optimized by ensuring low-carbon products and sophisticated technology in the food processing industry (Milczarski *et al.*, 2021). For instance, efficiency in boilers can be achieved completely differently. In boilers, energy is lost in various forms of heat; therefore, limiting heat loss can reduce fossil fuel usage, hence enhancing energy efficiency (Barma *et al.*, 2017). Furthermore, together with technological innovation, economic reform can ensure energy efficiency, whereas excessive economic activity instigates energy consumption (Chen *et al.*, 2021). Hence, by narrowing technology gaps, energy efficiency might be achieved which assists in reducing carbon emissions and conserving energy (Ouyang *et al.*, 2022). It is evident that factors such as gross domestic product (GDP) growth and trade openness boost energy consumption. However, technical advancement ensures energy efficiency by reducing energy use (Sohag *et al.*, 2015).

On the other hand, changes in energy prices cause fluctuations in demand, which might affect the demand for manufacturing inputs. In particular, electricity is one of the most essential forms of energy, whose demand and price variations are intertwined, with some aspects, such as the demand for labor and capital, being highly influenced by the fluctuations in electricity price (Bölük & Koç, 2010). Therefore, energy forecasting is needed to foresee future energy demand and manage it efficiently. For effective energy management and a sustainable future, Bangladesh should prioritize technological innovation alongside other concerns (Islam, 2021).

The review paper contributes to the collection of theoretical and analytical models that researchers and practitioners can use for quantitative, qualitative, or mixed-approach research and practices (Paul & Criado, 2020). This study enriches extant literature in this area of study and provides a complete summary of existing literature with critical analysis. Likewise, it identifies future research avenues and provides research directions (Rowley & Slack 2004). Therefore, it becomes easier to find research gaps and create avenues for further studies (Paul & Criado, 2020). This review also serves as a guide for government, development agents, policy makers, scholars, businesses, entrepreneurs and relevant stakeholders, working in the energy sector and food processing industry in Bangladesh.

CONCLUSION

The economic activities are gradually increasing in Bangladesh and it creates extra pressure on the energy. Energy efficiency should be achieved through technological breakthroughs and other possible measures in the future to meet Bangladesh's massive energy consumption, particularly in the food processing industry. Hence, efficient energy use and effective management in food processing plants, are to be highly encouraged for lowering costs, conserving fossil energy sources, and limiting environmental degradation (Clairand *et al.*, 2020). In this backdrop, this paper explores the previous works on energy demand, possible energy-saving technology and achieving efficiency nexus in Bangladesh with a specific reference to the food processing industry. The findings reveal that energy demand in Bangladesh is influenced by a variety of macroeconomic and other factors, and that implementing energy-saving technologies might be one of the determinants for increasing energy efficiency and, as a result, lowering energy demand. Considering the limited availability of energy sources, energy-saving technology can be a strategic solution to meet the projected energy demand in the days to come. Acknowledging this view, actions at the policy level must be taken and implemented to adopt energy-saving practices and more importantly, incentives should be offered to buy and employ energy-saving technologies (Clairand *et al.*, 2020). Therefore, all the actors must step forward to work together for addressing the challenge of achieving energy- efficiency by utilizing many strategies and like technology.

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