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GREEN FINANCE AND LOW-CARBON ECONOMIC RECOVERY IN THE POST COVID-19 WORLD

Nexus between green financing, renewable energy generation, and energy efficiency: empirical insights through DEA technique

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Abstract

The study aims to test the nexus of green financing with renewable electricity generation and energy efficiency. The study used data envelopment analysis (DEA) technique during the year of 2016 to 2020 in developed and developing countries. The findings show that there is a 24% possibility of worldwide rise in expenditures in renewable energy through energy efficiency projects and probably could fall around 17% much further in 2017 and 2018. This may jeopardize the Sustainable Development Goals (SDGs) and the Paris climate change agreement. Lack of access to private financing slows the development of green initiatives. Now that sustainable energy is not about science and technology, it is all about getting financing in developed and developing countries. As policy measure, the study suggested to value environmental initiatives, like other infrastructure initiatives, for greater electricity generation and energy efficiency in developed and developing countries. Such infrastructural projects need long-term financing and capital intensiveness. It is further suggested to sustain growth, development, and energy poverty reduction, and around $26 trillion would be required, in terms of green financing, in the developed and developing countries alone by the year 2030 to enhance energy efficiency. To achieve energy sustainability goals in developed and developing countries, recent research suggested some policy implication considering the post COVID-19 time. If such policy implications are implemented successfully, there are chances that green financing would make energy generation and energy efficiency effective.

Keywords Green financing · Energy efficiency · Environmental initiatives · Post COVID-19 period · Climate change

Introduction

There is a possibility that worldwide expenditures in renewable energy and energy efficiency projects could fall much further in 2017 and 2018 (Mohsin et al. 2020b, 2018, 2021). This may jeopardize the Sustainable Development Goals (SDGs) and the Paris climate change agreement. Lack of access to private financing slows the development of green initiatives. Now that sustainable energy is not about science and technology, it is all about getting financing (Mohsin et al. 2019, 2020a, 2021). A lot of people regard environmental initiatives, like other infrastructure initiatives. Infrastructural projects are long-term and capital-intensive. The Asian Development Bank claims that to sustain growth, development, and poverty reduction, $26 trillion would be required in the area alone by the year 2030. The majority of the $14.7 trillion overall investment requirements for the period 2016–2030 will be for energy (power).

When it comes to green energy initiatives, two key problems exist: (a) lesser returns and (b) a larger risk of investment. Banks do not fund green energy projects because of the inherent risk and because of the Basel capital requirements (Yang et al. 2021; He et al. 2020; Mohsin et al. 2020b). Risk is difficult to protect since traditionally, utility prices were distributed among customers in regulated utility

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service. But because of the absence of PPA contracts in developing nations, uncertainty is increased and investment is made riskier. The third main factor for the shrinking new investment in renewable energy is fast technology advancement and cost reduction. Renewable energy technologies cost less thanks to technology advancements. Averaged over the 2009–2016 period, PV module costs have decreased by 80%, while wind turbine costs have decreased by between 30 and 40%. However, this news leads investors to halt and observe how far the prices would fall on the opposite side (Tiep et al. 2021).

Problems for renewable energy continued with the COVID-19 outbreak. Incubation of corona-positive individuals (a health emergency) combined with a fall in the energy market because of unanticipated decrease in oil prices (Ikram et al. 2019a; Shah et al. 2019). As a result, these challenges plunged world economies into a recession . Besides, efficiency is influenced by climate change and improved responses of carbon emission during the epidemic (Alemzero et al. 2021). The estimations revealed that during pandemic lockdown, 17% of the world's climatic changes were recorded, and this shift decreased energy efficiency by 32%. Carbon output is projected to decrease in the pandemic era, and there is a likelihood of a 1.2% drop in energy efficiency. Another research (Ikram et al. 2019a, 2019b; Sun et al. 2019) found that the COVID-19 crisis had caused a 10% decline in energy efficiency. This suggests that more populous and oil-addicted nations witnessed a major decrease in energy efficiency (Sun et al. 2020d; Baloch et al. 2020).

Renewable power production and energy efficiency funding have been seen as significant concerns in rising seven economies as resource-intensive and carbon-based growth increases . Carbon-intensive economies are also popular growing economies. The two estimates show a large growth in the PE in the USA, Japan, and the rest of the world's global renewable electricity generation (Sun et al. 2020c, 2020d, 2020e). Emerging nation's population rose by 36%, from 2.9 billion to 4.0 billion, throughout the decade 2000–2015. Asia is poised to have a major impact on the world's food security as it grows in significance with respect to population and economic power in the latter option. Many nations, particularly those in the early phases of development, are vulnerable to losing both their environmental variety and health from climate change. Increased environmental change now boosts the need for solid and long-term energy solutions (Chandio et al. 2020; Sun et al. 2020c). Greening the economy is the most powerful path to take. Sustaining the energy system and increasing energy efficiency need some proactive public assistance. Also, this fosters economic resource mobility and economic development under eco-environment openness (Alemzero et al. 2020a, 2020b; Sun et al. 2020c). So governmental incentives to promote energy efficiency help spur green development by reducing carbon emissions. Reducing our reliance on fossil fuels is important in today's time, amid the COVID-19 epidemic. The latest research contributes to a better understanding of critical factors that influence public supports for renewable energy. Too far, no comprehensive research on renewable energy and public support has been done. While public papers from various government agencies and ministries offer the foundation for future research in linking these constructions, it can give theoretical assistance in creating the theoretical framework connecting public subsidies and energy efficiency in crisis periods. During the period from 2014 to 2017, $2 trillion will be spent in these three sectors following the COVID-19 outbreak. Public sources said that $X in green energy financing will be spent in renewable, clean, and green energy projects (Sun et al. 2020a, 2020b).

Extending to it, green financing has become a vital way forward to finance for the environment-related issues to clean. Such financing technique is modern tool giving way to the global world for financing and managing environment and growth-related aspects helping economies to sustain and grow on green basis. In short, green financing through green financing is modern solution to the globe for green development. One of the obstacles for green development is how to effectively finance green projects from the public, private, and not-for-profit sectors (UN Environment). This argument unlocked the new avenues of financing and holds the potential to replace traditional modes of financing, such as government subsidies and public financing. Importantly, there is a dire need to develop the market mechanism that can pool financial markets more effectively to fund green projects.

Green financing is the latest financing option. Previous studies highlighted that green financing are less studied in the domain of renewable electricity generation energy efficiency systems and warranted to investigate to add up in the body of knowledge by giving solutions for post COVID-19 time. To the best of our reading, no research has involved energy efficiency investment and economic growth, nor is there a study on how to manage the post COVID-19 time. However, there is a need to test energy efficiency associated with green financing with renewable electricity generation for energy efficiency and to present the policy implications controlling the post COVID-19 tenure. Hence, the objective of the study is to test this novel connection between these constructs and present best possible solutions to the associated stakeholders. The study measures the energy efficiency of developed and developing countries. We also proposed a policy framework.

The study is structured into five different portions containing the "Introduction" section as introduction, the "Literature review" section discusses the review of literature, the "Data and methodology" section comprises research methodology, the "Results and discussion" section elaborates the findings and discussion on study results, and the "Conclusion and policy implication" section presented the conclusion and implications for stakeholders.

Literature review

Many countries the cleanest environment of any nation in the world, are excelling in air quality, sanitation, clean drinking water, waste management, and addressing climate change, and aim to reduce GHG emissions by 70% by 2030 (Agyekum et al. 2021; Zhang et al. 2021a). A long history of success in renewable energy development is evident. Developing renewable energy to stabilize the environment is something to learn from this all. This is evidence that the government can close the gap between investment payments and renewable sector revenues by implementing suitable legislation. Most electricity in Denmark is generated by wind power. This nation has long relied on foreign oil. Energy dependence did not begin until the post-1973 oil crisis. Ever since then, Denmark has poured millions into renewables, notably wind power. Renewable output accounted for 47% of total energy output in 2019. Denmark's aims are to provide more than half of their energy needs with renewables by 2030 and to have gotten rid of fossil fuels for energy production by 2050.

A whole supply chain from commodities to components has been impacted by the COVID-19 epidemic. This is clear, since the power production in Denmark initially dropped since 2000. Other studies demonstrate that the reduction in gross power output may be linked to the reduction in net power output from wind turbines . Bloomberg New Energy Finance has suggested that overdependence on a single kind of renewable energy might be detrimental during emergency situations. The following discussion accounts for our findings. The outcomes of the COVID-19 pandemic are likely to vary greatly over the world, as a result of regional, national, and geopolitical factors. Therefore, unique characteristics, such tight containment procedures, first-aid, or palliative care, give information on the consequences of the pandemic. Delay of infection seemed to be less in Denmark compared to other European nations because of the installation of stringent lockdown, social distance, and government assistance (Banerjee et al. 2021). The short- and long-term consequences of these policies are without debate.

This mission complements the ultimate objective of sourcing all of the energy from carbon-free, environmentally-friendly sources. Renewable power production has risen over the last decades and still has a significant potential. Since renewable energy sources have major economic implications, we must investigate how it is generated to comprehend the economic state post-pandemic. Recently, a literary strand has explored environmental innovations' involvement with financial issues. Environmental innovation literature is sparse according to Johnson, and Stoian and Iorgulescu (2020) conducted a study on environmental innovations among small- and medium-sized companies inside the European Union, finding that financial constraints impede business' environmental innovations. To boost environmental innovation adoption and facilitate access to financing, Goldstein et al. (2021) investigated the influence of funding limitations on innovation activities across 1300 European enterprises during the 1995–2009 period by using patents as a proxy for innovation and three other financial variables as funding sources. In order to advance innovative projects, it is essential to remove finance constraints. Despite (Deardorff et al. 2020) explanatory study which attempts to prove a connection between funding and green innovation, the scant research on finance restrictions on green innovation persists.

Further, funding limits will vary depending on the form of ownership. The available research demonstrates that SOEs have primarily been able to spend in R&D for innovation because of loan guarantees and access to state-owned banks. However, another branch of research argues that state ownership and political features are not the driving forces in the private equity market, and so raise financing limit. Additionally, Victor et al. (2021) observed that state ownership affects investment in R&D by loosening finance limitations and constraining the innovativeness of state-owned companies.

Since investing in energy efficiency would boost contract win rates, it also boosts the usage rates of the ships, and that may be a significant consideration in an oversupplied market. Despite that, energy efficiency is unlikely to be completely reflected in charter prices owing to the ambiguity as to whether the market would compensate for fuel efficient ships. Ship-owners must either own their own ships or enter into long-term arrangements with charterers if they want to recuperate their investments in fuel economy. Furthermore, Azad et al. (2021) observe that charterers may be hesitant to pay a premium to represent energy efficiency, since it might decrease the number of potential charter customers by driving up shipping costs. Verifying fuel usage claims given by the owners also adds to that resistance. Ship management organizations' wariness about charter fees for both energy efficiency and investment in energy efficiency was also mentioned by Mosser (2020). Thus, the debate regarding the effects of energy efficiency relies on new technology, notably the financial risk associated with unproven fuel savings. Adding more costly, environment-friendly fuel is connected with slower speed and longer cargo time. However, better fuel quality does not seem to effect ship speed (Cui et al. 2021).

In addition, there is very little evidence that financial savings accrued from shipping fuel-efficient ships incentivizes ship-owners to purchase more fuel-efficient ships. In the instance of dry bulk shipping, Zhang et al. (2021b) found that only 40% of the financial savings achieved by energy efficiency is received by ship-owners. Other dry bulk ship sizes were also covered in Rasoulinezhad et al. (2020). Less than half of the fuel cost reductions are shared with ship-owners by means of increased time charter charges, and only under normal market circumstances. Additionally, inefficient tonnage is often rewarded in rising markets. This has important implications for how time charter contracts set prices for energy efficiency. During prosperous times, owners of energy efficient tonnage might be punished. There are different techniques that advance energy systems.

It is interesting to note that renewable energy sources have considerable potential to preserve current energy consumption patterns and energy efficiency, but to do so, there is a large deal of public support required. The International Energy Agency (IEA) calculated a total public support need of roughly $16 trillion USD, stretching from 2015 to 2050. This idea is in line with the Paris Agreement objective commitment. However, in the energy sector, support for energy efficiency is sluggish going (Li et al. 2021; Chien et al. 2021; Iqbal et al. 2021).

Data and methodology

Data

From two separate yearly polls conducted by the USA, data was obtained to help carry out our empirical study (EIA). In other words, surveys Form EIA-923 and Form EIA-861 should be done. Power plant operating parameters were measured using the EIA-923 form on an annual basis, starting in 2013 and ending in 2017. In order to give information on the frequency and length of electricity system interruptions experienced by end-consumers, the EIA compiled data for the study of Form EIA861, which they had been collecting since 2013. Some utilities submitted data ranging from a few years to many decades. As a consequence, our data set has 198 yearly observations between 2016 and 2020, with just half of the data included in each of those years.

Measurement of the constructs

SAIDI is a score used to determine the length (typically measured in minutes) of interruptions in the power supply for end-users. The average time interruption lasts, which is often referred to as the system average interruption frequency index (SAIFI) (i.e., the number of times a customer has gone without power during the year) (1998). In standard terminology, the two indices are used by utilities that want to track the overall quality of their electrical grid (Agosto and Giudici 2020). In a DMU division, Tone uses slack-based effectiveness determination to find a unique opportunity (i.e., opportunity indicated by DMUj, ($j = 1\ldots, n$). For this, an output unit serving the DMU for the empirical estimate is established that serves the DMU, which is fed with x, which is set to R mk^+; y, which is set to R sk^+; and z, which is set to Rdk^+. More so, the invention opportunity indicates two-stage subsets with the following arrangement:

$$\mathrm{PPSstage1} = \{(\mathrm{x},\mathrm{z})|\mathrm{x} \geq \sum_{j=1}^{n} \chi_j \lambda_j, z \leq \sum_{j=1}^{n} z_j \lambda_j, \mathrm{j} = 1, \ldots, \mathrm{n}\} \quad (1)$$

$$\mathrm{PPSstage1} = \{(\mathrm{y},\mathrm{z})|\mathrm{z} \geq \sum_{j=1}^{n} z_j \mu_j, y \leq \sum_{j=1}^{n} y_j \mu_j, \mathrm{j} = 1, \ldots, \mathrm{n} \quad (2)$$

DMUk application adoption is a potential invention opportunity, which reveals its capability when extended with a dual-step identification that demonstrates DMUk's declaration of consistency evolved to the point where it could survive a construct with ejected well-organized units, and which show that the system could survive amorphous conditions. However, the study done on competent position DMUs employs an association structure. Therefore, the intermediate trial's weakness may impact the overall effect. The contribution of midway meals must be taken into consideration while assessing the efficiency and positioning of the competent unit. However, the study shows a novel connected and integrated model using the ranking method on the basis of outputs generated by the fundamental occurrence.

$$r_k = \min\Big(\frac{1}{m}\sum_{j=1}^{n}\frac{\mathrm{s}_\mathrm{i}^-}{\mathrm{x}_\mathrm{ik}} + \frac{1}{D}\sum_{d=1}^{D}\frac{T_d^*}{z_{dk}}\Big)/\Big(1 + \frac{1}{D}\sum_{d=1}^{D}\frac{R_d^*}{Z_{dk}} + \frac{1}{S}\sum_{r=1}^{S}\frac{s_r^+}{y_{rk}}\Big) \quad (3)$$

$$\mathrm{s.t.}\sum_{j=1}^{n}\lambda_j x_{ij} + \mathrm{s}_\mathrm{i}^- = \mathrm{x}_{\mathrm{ik},}\ \mathrm{i} = 1, \ldots, \mathrm{m},$$

$$\sum_{\substack{j=1 \\ j \neq k}}^{n} \mu_j y_{rj} - s_r^+ = y_{rk},\ \mathrm{r} = 1\ldots, \mathrm{s},$$

$$\sum_{\substack{j=1 \\ j \neq k}}^{n} \lambda_j z_{dj} = z_{dk} + R_d^*,\ \mathrm{d} = 1, \ldots, \mathrm{D},$$

$$\sum_{j=1, j\neq k}^{n} \lambda_j z_{dj=} z_{dk-} T_d^*,\ \mathrm{d} = 1 \ldots, \mathrm{D},$$

$$s_r^+ \geq y_{rk,}\ \mathrm{r} = 1, \ldots, \mathrm{s},$$

$$s_i^- \geq 0,\ \mathrm{i} = 1, \ldots, \mathrm{m},$$

$$s_r^+ \geq 0,\ \mathrm{r} = 1, \ldots, \mathrm{s},$$

$$\lambda_j \geq 0, \mu_j \geq 0,\ \mathrm{j} = 1, \ldots, \mathrm{n}.$$

In Eq. (3), an objective model is formed on the basis of supposed DMUs with n, whereas m indicated the variety of inputs ${}^{x}{}_{j} = ({}^{x}{}_{1j}, \ldots, {}^{x}{}_{mj})$ covering the scope of different non-energy sources and other power sources aligned with the range of yield customs, such as $g_j = (g_{1j}, \ldots, g_{sj})$ and $b_j = (b_{1j}, \ldots, b_{fj})$, indicated with f an undesired function for an output (de España 2020; Navon et al. 2020). Endorsing Eq. (9) in the recent tests, the RAM-DEA model has been used to quantify the power efficiency in unusual discard scenarios for each DMU. Attributes that are un-identical to each other but nonetheless connected are determined by the model's limitations.

$$max_{s,\lambda} \sum_{i=1}^{m} R_i^x s_i^x + \sum_{r=1}^{s} R_r^g s_r^g + \sum_{f=1}^{h} R_f^b s_f^b \tag{4}$$

$$s.t. \sum_{j=1}^{n} x_{ij} \lambda_j + s_i^x = x_{ij0}, i = 1, \ldots, m$$

$$\sum_{j=1}^{n} g_{rj} \lambda_j - s_j^g = g_{rj0}, r = 1, \ldots, s$$

$$\sum_{j=1}^{n} b_{fj} \lambda_j + s_f^b = b_{fj0}, f = 1, \ldots, h$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, j = 1, \ldots, n s_i^x \geq 0, i = 1, \ldots, m$$

$$s_r^g \geq 0, r = 1, \ldots, s s_f^b \geq 0, f = 1, \ldots, h$$

For empirical analysis, DEA-based technique is used to assess the interplay between constructs in empirical way. However, study applied DEA technique to present the inference between the constructs.

$$\begin{gathered} min\theta \\ s.t. \sum_{r=1}^{m} \theta \boldsymbol{d}_r \lambda_r \leq \theta \boldsymbol{d}_m, \sum_{r=1}^{m} \theta \boldsymbol{e}_r \lambda_r \geq \boldsymbol{e}_m \\ \lambda_r \geq 0, r = 1,2, \ldots, m, \theta \in E^1 \end{gathered} \tag{5}$$

Any optimal solution θ and λ of model (5) can be solved by linear programming. The value of θ will not surpass 1. In the DEA model, if $\theta < 1$, the DMU is ineffective, and if $\theta = 1$, the DMU is effective.

$$\begin{gathered} min[\theta - \varepsilon(e_1^T g^- + e_2^T g^+)] \\ s.t. \begin{array}{c} \sum_{r=1}^{m} \theta \lambda_r d_{kr} + g^- = \theta d_{kr}, k = 1,2, \ldots, i \\ \sum_{r=1}^{m} \theta \lambda_r e_{lr} - g^+ = \theta e_{lr}, l = 1,2, \ldots, j \\ \lambda_r \geq 0, r = 1,2, \ldots, m \\ g^+ \geq 0, g^- \geq 0 \end{array} \end{gathered} \tag{6}$$

The DEA method uses input and output variables. They are the primary step in efficiency analysis and may lead to inaccurate results by choosing unrepresentative factors. The data set must have acceptable values, and the input and output types must be appropriate for each DMU in the same unit. A tight correlation between each input and output is required (Ishaq and Dincer 2020; Khan et al. 2019). DEA models may concentrate on input or output. In input-oriented models, optimization means decreasing inputs while maintaining output. Output is maximized in the second case (outcome designs). Choosing the appropriate model is critical when calculating technical efficiency using DEA. The output-oriented paradigm is suitable for organizations like banks that aim to maximize profit. NGOs or public hospitals are examples of DMUs that benefit from the input-oriented strategy.

Results and discussion

Empirical results

This study findings shows that in Austria in Finland and together are considered a single region as a result of increasingly high energy efficiency and market reforms in Austria due to lack of separate data in Luxembourg. The model results of these countries therefore are many studies deal with energy efficiency and market changes, but do not reach the highest possible degree of energy efficiency. This research thoroughly proposes the creation of lower-cost power supplied across border nations for renewable energy marketplaces. This present research focuses on 28 high carbon-strong market reforms for new targets and low emissions with high primary energy dependence. We must also characterize these nations, their provinces, autonomous regions, and municipalities further in terms of development and political considerations usually in three major categories: east, central, and comprehensive data on areas and regions is shown in Table 1 and Table 2.

As indicated in Table 2, the eastern area includes 11 regions including eight coastal provinces, the fastest economic development in the past 30 years in those nations, and the average GDP output throughout the research period (2010–2014) accounting for almost half of the total GDP in these countries. Most lighting and many heavy industries are situated in the eastern area, and the majority of foreign industrial and commercial services in those nations are located. This region also draws the biggest international investment and technology thanks to its comfortable transit system and infrastructure. These nations have high access to GDP and highest power use in all sectors. Today, greenhouse gases with green energy sources such as wind, solar, thermal, and biogas are decreasing throughout the globe. Market changes are extremely beneficial to academics, researchers, and governments.

In this region, economic development, attractiveness, and technology are less than in the East, but greater than in the west. In the north-east, there are also heavy industries. They are producing and exporting millions of tons of coal eastwards. Higher technology boosts the economy of the nation and confronts the CO_2 emission countries with the finest power reforms. Based on the aforementioned findings, we concluded that technological development is one of the key reasons for energy efficiency and electricity reform. This development typically involves a decrease in the intensity of energy. Even while this decrease in energy intensity in some developing economies such as Austria has already been seen, it is still greater than many other nations in the globe, particularly highly developed ones. In this instance, it is an efficient method to increase energy efficiency using energy technology for emerging countries. Furthermore, it has been noted that most developing and rising countries still rely significantly on non-renewable energy sources such as fossil fuels and coal despite their active reform of their energy consumption structures as well as their strong efforts to create clean energy and renewables. Therefore, the basic structural adjustments in energy production, distribution, and consumption seem to be required. Reforms on

Table 1 Energy efficiency score—DEA methodology outputs from 2016 to 2020

Countries	2016	2017	2018	2019	2020
Austria	0.344	0.656	0.467	0.557	0.707
Azerbaijan	0.178	0.532	0.883	0.589	0.319
Belgium	0.444	0.471	0.455	0.781	0.444
Chile	0.732	0.314	0.555	0.789	0.567
Finland	0.616	0.319	0.446	0.885	0.481
Germany	0.222	1.000	1.000	1.000	0.513
Denmark	0.567	0.370	0.441	0.456	0.289
Fiji	0.707	0.719	0.979	0.975	0.990
France	1.021	1.000	0.856	0.434	0.389
Ghana	1.000	1.000	1.000	1.000	1.000
Hungary	1.000	1.000	1.000	1.000	0.011
India	0.999	0.333	0.275	0.389	1.000
Iraq	0.457	0.481	0.513	0.889	1.000
Sweden	1.000	1.000	1.000	1.000	1.000
Italy	0.221	0.894	1.000	1.000	0.446
Bulgaria	0.222	0.356	0.358	0.188	0.306
Croatia	0.243	0.671	0.280	0.888	0.132
Jordan	0.267	0.456	0.289	0.356	0.441
Malta	1.000	1.000	0.456	0.444	1.000
Mongolia	1.000	1.000	1.000	1.000	1.000
Vietnam	0.708	0.837	0.527	0.234	0.275
Oman	0.456	0.566	0.187	0.384	0.255
Pakistan	0.129	0.316	0.271	0.255	0.046
Russia	0.894	0.319	0.388	0.110	1.000
Poland	0.121	0.477	0.498	0.489	0.671
Romania	0.355	0.787	0.356	0.439	0.356
Taiwan	0.354	0.990	0.289	0.241	0.558
Qatar	0.132	0.558	0.345	0.306	1.000

Table 2 Weighted data scores

DMU	Scores	VX 1 (GF)	UY 1 (REG)	UY 2 (EE)
Austria	0.311	0.64	0.33	0.70
Azerbaijan	0.144	0.51	0.29	0.88
Belgium	0.432	0.40	0.11	1.00
Chile	0.744	0.36	0.01	0.33
Finland	0.622	0.39	0.99	0.11
Germany	0.216	0.27	0.00	0.40
Denmark	0.507	0.24	0.13	0.84
Fiji	0.767	0.17	0.19	0.27
France	1.004	0.37	0.66	0.51
Ghana	1.654	0.78	0.14	0.60
Hungary	1.499	0.81	0.21	0.45
India	0.960	0.33	0.34	0.83
Iraq	0.490	0.41	0.20	1.00
Sweden	1.221	0.67	0.18	0.44
Italy	0.201	0.84	0.67	0.38
Bulgaria	0.145	0.36	0.80	0.21
Croatia	0.267	0.71	0.55	0.77
Jordan	0.201	0.21	0.32	0.49
Malta	1.484	0.16	0.11	0.11
Mongolia	1.734	0.89	0.17	0.55
Vietnam	0.756	0.19	0.18	0.00
Oman	0.429	0.51	0.44	1.00
Pakistan	0.194	0.32	0.80	1.00
Russia	0.821	0.23	0.79	0.45
Poland	0.190	0.70	0.00	0.99
Romania	0.354	0.71	0.00	0.82
Taiwan	0.332	0.10	0.00	0.46
Qatar	0.101	0.55	0.56	0.67

the markets presently play a significant influence in national advances in renewable energy. The fast economic developments in developing countries such as Austria have drawn lots of attention from the government, academics, and the public.

In order to solve the problem of excessive energy consumption, a succession of energy conservation laws has been established after the twenty-first century. Officials, as policy-makers and executors, are certainly one of the main factors in resolving this issue. According to BP World Energy Statistical Review, Austria's total energy consumption occupied 23.2% of the worldwide market in 2017, holding top place for several years. Thus, improving energy efficiency has become important tasks to accomplish for growing economies such as the Chinese government.

Figure 1 shows renewable energy efficiency. In recent years, a number of energy and electricity regulations were adopted in power sector in emerging countries, and the energy efficiency of generation, consumption, or distribution is anticipated to be increased efficiently. The electricity industry is regarded one of the leading drivers of economic development. The installed thermal power plants that account for more or less 75% of the total capacity were generated in the emerging countries. Coal is the major electrical fossil fuel, representing 90% of the thermal capacity built. Emerging countries such as Denmark are continually increasing its energy demand fast, and this increasing requirement continues to be fulfilled via fossil fuel use, especially through coal burning for electricity. In 2018, electricity consumption was recorded up to 303.2 billion kilowatts an hour in a single developing country like Turkey, therefore indicating projected rise to 357.4 terawatts an hour (approximately 5.5% increase) by 2023. Furthermore, Turkey's energy consumption indices showed that coal was generated by 37.3% of power production in 2018, while gas, hydropower, wind, solar, geothermal, and other sources jointly produced by 29.8%, 19.8%, 6.6%, 2.6%, and 2.5% in the same year. This explains the electricity percentage quantification. As heavy industries in certain areas of this sector are very densely involved, energy consumption and associated pollutant emissions are considerable.

Role of green finance

The west spans more than half of the area of these nations and covers one municipality. This region also has a low population density and a large stock of resources such as coal, oil, natural gas, and other minerals in the other two places. The western region of these nations is also the least developed territory. However, it is well protected in certain parts of this area owing to the low density of industry and people. Table 3 compares the role of green financing in the three economics regions before and during COVID-19 wave.

Figure 2 shows that Luxembourg as Asia Pacific's fastest growing economy has the greatest energy efficiency score of 1.596 and rank 1 in the area. Although Luxembourg's energy efficiency varied between 2010 and 2014, it tended to decline at an annual rate of 1.23%. The Netherlands and Germany rank second and third with respective energy efficiencies of 1.527 and 1.157, which continue to rise at an average yearly pace of 1.93% and 0.73%. Sweden and Ireland rank fourth and fifth with energy efficiency of 1.056 and 0.818, respectively.

However, Sweden's energy efficiency continues to decline at an annual average rate of 1.89%, unlike Ireland, where energy efficiency continues to improve. Italy and Spain rank sixth and seventh with energy efficiency score of 0.659 and 0.492, respectively. UK and Portugal rank eighth and ninth with energy efficiency score of 0.398 and 0.261, respectively. Belgium and Finland rank 10th and 11th, with energy efficiency of 0.246 and 0.233, respectively. Poland and Denmark rank second and thirteenth with energy efficiency score of 0.221 and 0.204, respectively.

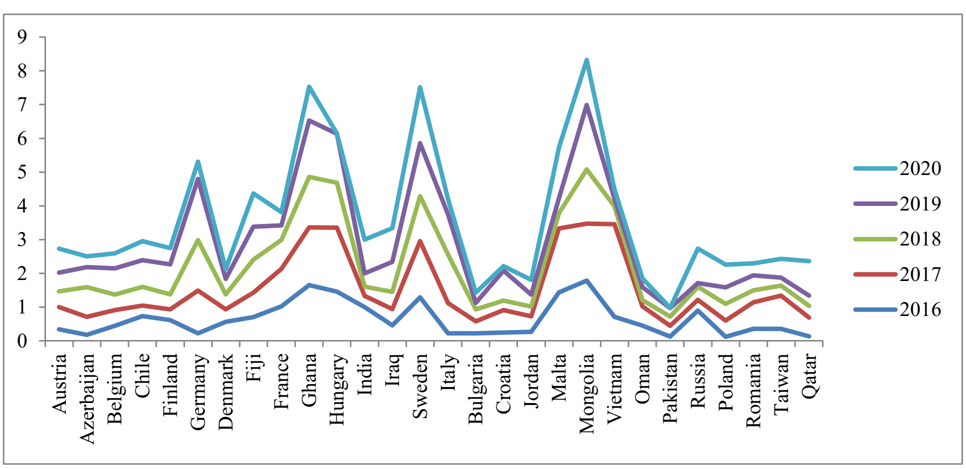


Fig. 1 Renewable energy efficiency through electricity generation

Table 3 Role of green financing before and during COVID-19 wave

DMU	Before COVID-19 score	Energy efficiency	After COVID-19 score	Energy efficiency
Austria	0.00	0.70	0.91	0.56
Azerbaijan	0.1	0.88	0.35	0.71
Belgium	0.00	1.00	0.18	0.17
Chile	0.04	0.33	0.90	0.21
Finland	0.02	0.11	0.67	0.07
Germany	0.06	0.40	0.80	0.07
Denmark	0.05	0.84	0.45	0.33
Fiji	0.00	0.27	0.66	0.11
France	0.00	0.51	0.78	0.13
Ghana	0.01	0.60	0.91	0.44
Hungary	0.09	0.45	0.17	0.20
India	0.56	0.83	0.88	0.17
Iraq	0.03	1.00	0.44	0.67
Sweden	0.02	0.44	0.21	0.23
Italy	0.06	0.38	0.70	0.14
Bulgaria	0.135	0.21	0.67	0.01
Croatia	0.07	0.77	0.99	0.30
Jordan	0.21	0.49	0.89	0.21
Malta	0.44	0.11	0.91	0.08
Mongolia	0.34	0.55	0.77	0.05
Vietnam	0.74	0.00	0.72	0.67
Oman	0.21	1.00	0.33	0.34
Pakistan	0.00	1.00	0.29	0.15
Russia	0.00	0.45	0.89	0.34
Poland	0.00	0.99	0.44	0.21
Romania	0.00	0.82	0.55	0.05
Taiwan	0.00	0.46	0.61	0.18
Qatar	0.00	0.67	0.80	0.22

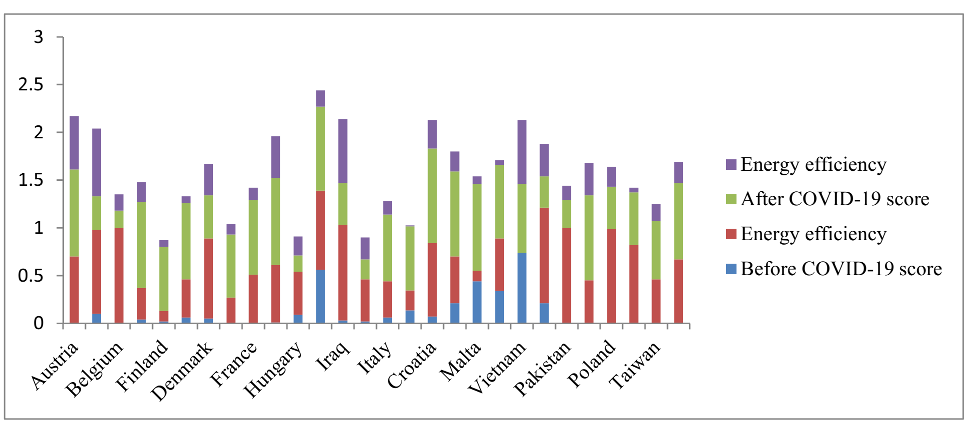
Figure 3 shows case-wise indicators and sensitivity analysis. Croatia and Austria rank fourteenth and fifteenth with 0.203 and 0.202 energy efficiency score, respectively. Greece and France rank seventeenth and seventeenth with energy efficiency score 0.176 and 0.170, respectively. Bulgaria and Czech Republic are eighteenth and nineteenth with energy efficiency score of 0.163 and 0.159, respectively. Romania and Estonia rank twenty-first and twenty-first, with energy efficiency of 0.142 and 0.141, respectively. Malta and Slovenia rank twenty-second and twenty-third, with energy efficiency of 0.139 and 0.136, respectively. Slovakia and Hungary ranked twenty-fourth and twenty-fifth with energy efficiency of 0.123 and 0.121, respectively. Cyprus, Lithuania, and the latter are ranked twenty-sixth, seventh, and eighth with an energy efficiency score of 0.107 0.099 and 8.56, respectively. Table 4 shows the sensitivity analysis.

In this study, we use annual capital and labor data as two non-energy inputs and energy consumption as we use gross domestic product (GDP) as the desired product and renewable energy generation as unwanted products.

Robustness analysis

We've used sensitivity analysis to find out how stable energy efficiency by using a new data set of [15% variation]. Policy messages that may be sent are because of faulty structure or improper interpretation of complete collection of input and outputs. Table 5 shows energy efficiency after green financing. Furthermore, inferring from the analysis, expenditure on education and research and development can stimulate greening the economic system activity. Thus, heads of state should devote more funding to these areas. They are the catalyst to the future and present sound greening economic expansion as well as human resource development and technological advancements. Most often investment projects not having significant landmarks regarding executing the project might end up being disrupted, not satisfying the aims of the country's meeting needs. In this vein, it is fitting. We think to have an effective channel of communication among the tri parties in delivering these projects: the donors, governments, and the green economic sectors.

Fig. 2 Green financing influences on study constructs



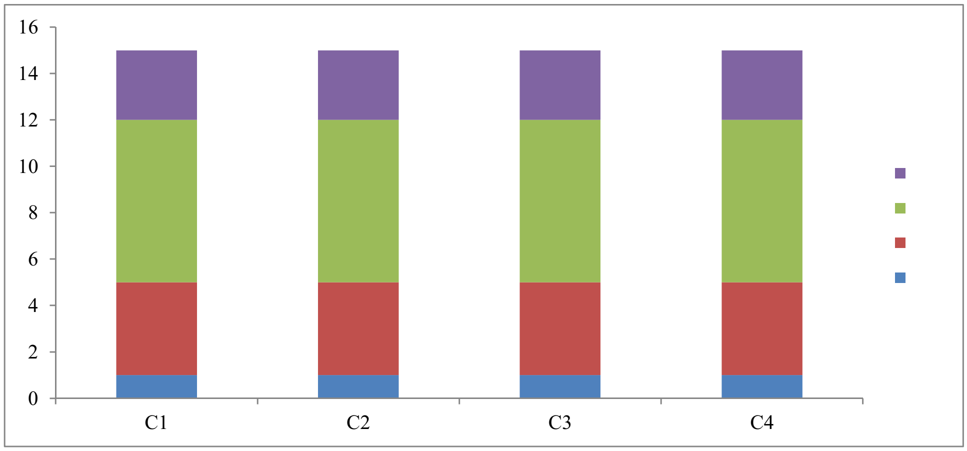


Fig. 3 Case-wise role of indicators and their sensitivity responses

Table 4 Findings of sensitivity analysis

	Case rank	Case 1	Case 2	Case 3	Case 4
PS1	1	1	1	1	1
PS2	4	4	4	4	4
PS3	7	7	7	7	7
PS4	3	3	3	3	3

Table 5 Energy efficiency after green financing

Countries	2016	2017	2018	2019	2020
Austria	0.37	0.67	0.42	0.58	0.76
Azerbaijan	0.18	0.53	0.88	0.59	0.32
Belgium	0.44	0.47	0.46	0.78	0.44
Chile	0.73	0.31	0.56	0.79	0.57
Finland	0.62	0.32	0.45	0.89	0.48
Germany	0.72	0.77	0.80	1.00	0.51
Denmark	0.57	0.37	0.44	0.46	0.29
Fiji	0.71	0.72	0.98	0.98	0.99
France	1.00	1.00	0.86	0.83	0.39
Ghana	1.00	1.00	1.00	1.00	1.00
Hungary	1.00	1.00	1.00	1.00	1.00
India	1.00	0.33	0.28	0.39	1.00
Iraq	0.46	0.48	0.51	0.89	1.00
Sweden	1.00	1.00	1.00	1.00	1.00
Italy	0.22	0.89	1.44	1.19	0.45
Bulgaria	0.22	0.36	0.36	0.19	0.31
Croatia	0.24	0.67	0.28	0.89	0.13
Jordan	0.27	0.46	0.29	0.36	0.44
Malta	1.00	1.00	0.96	0.84	1.00
Mongolia	1.00	1.00	1.00	1.00	1.00
Vietnam	0.71	2.75	0.53	0.23	0.28
Oman	0.46	0.57	0.19	0.38	0.26
Pakistan	0.13	0.32	0.27	0.26	0.01
Russia	0.89	0.32	0.39	0.11	1.02
Poland	0.12	0.48	0.50	0.49	0.67
Romania	0.36	0.79	0.36	0.44	0.36
Taiwan	0.35	0.99	0.29	0.24	0.56
Qatar	0.16	0.52	0.33	0.38	1.00

Additionally, there has to be linkage between academia and industry to scale up novel research such new technologies. Governments must give technical education a priority as this will be the foundation of rapid economic development through the reduction of costs of production via innovative technologies. Governments ought to de-risk the green investment space in the sub-region via policy instruments such as green credit and sustainable bonds. A necessary means to cutting down pollution is to move energy use from conventional sources to negative emission technologies such as wind and solar demand-pull programs in the sub-region for increasing the consumption of sustainable technologies like cost reductions, adopting a green living, green infrastructures like creating bicycle lanes, charging infrastructure, and giving tax holidays to wind and solar products. Redirecting high energy use from polluting sources to cleaner sources is the major problem for governments to implement. However, the point is the right policy makes the necessary change. These policies should aim to create an equitable, just and inclusive, and affordable program without externalities on the population.

Figure 4 shows energy efficiency after green financing. As a result of energy sector's risk tolerance, loans for technical development and research and development are very strict. The stock community on the other hand is more involved in high-risk, high-return technology research and development ventures and is able to disburse asset mortgage in technology and research and development. These both have negative effect on creativity production. Increase commercial size will yield maximum research and development funds for technology novelty, also enhances the fault tolerance rate, and provides quality output.

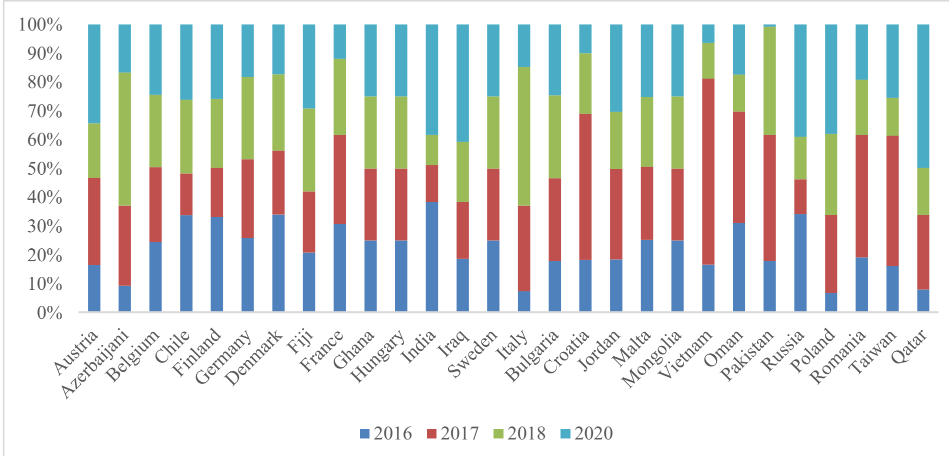


Fig. 4 Energy efficiency after green financing

Betterment in financial performance will gear up reservoir turnover, reduce funding limitation challenged by businesses coped in development, and result in more creative and productive production. Similarly, result explains the energy efficiency after green finance during 2016 to 2020. The results are also tabulated in Table 5. Romania, Azerbaijan, Denmark, Belgium, Chili, and Croatia faced a massive reduction in energy efficiency even after green financing during 2020. The persistence of COVID-19 crises is remained a main reason to it. While, Ghana, Iran, India and Sweden remained constant in energy efficiency, thanks to the good support of green financing. Only Austria has achieved significant rise in energy efficiency after green financing (see Table 5 and Fig. 4).

In order to grow rapidly and remain healthy, a tremendous quantity of energy is required. This means that any economy has a commitment to offer safe, sufficient, and inexpensive energy to producers and consumers. A study based on factual evidence has shown that Austria has the greatest overall rank in the environmental and energy standings. It is possible that this is related to the continuation of Austria policy on both energy and the environment. Although Austria imports an increasing amount of energy, it has set stringent duties and has developed efficient and clean and green energy consumption plans. To provide another example, the Austrian government has enacted measures to reduce pollution levels to 80% by 2050 . Carbon emissions generated by transportation are one of the greatest contributors to the UK's energy consumption, and a priority target of the government's clean air strategy is to reduce 40% of that pollution by 2020 while reducing 46% by 2030. To cut carbon emissions by 80% by the year 2050, Austria enacted a new climate change law in 2008. Environmental efficiency is enhanced when a sustainable economic structure is implemented. Additionally, for better environmental circumstances, there is a big role to play with regard to energy efficiency and energy intensity. More efficient use of conventional and renewable energy is required for this particular purpose.

Discussion

Under this scenario, most people in nations saw extremely high environmental efficiency. Meanwhile, we must understand that the non-parameter boundary approach is a technique to measure the relative effectiveness of decision-making units. At this time, however, the average environmental value for energy efficiency throughout the country was much lower than 96.02% (with "environmental regulation in the eyes of individual provinces, there is a significant difference in the environmental efficiency of two types of situations). A composite indicator combines multiple indicators into one index. The index is used to assess complicated ideas not captured by a single indicator. To create a meaningful composite indicator that may offer important decision-making information at national or worldwide level, the composite indexing process must be transparent to guarantee the future (Iqbal et al. 2021).

Lower renewable electricity generation increases energy efficiency with improved policy making in all research countries for future energy market. The research on renewable electricity generation focuses on market reforms and decrees on the impact of greenhouse gases on the environment (Iqbal et al. 2021). Energy efficiency drew significant attention from both academics and practitioners (Li et al. 2021). This increasing emphasis on energy efficiency relates to the significance of energy consumption in today's society. Energy, obviously, is the lifeblood of economic growth and an essential factor in a country's socio-economic development and power markets. No country can achieve economic development without huge energy. Countries must provide adequate and affordable energy supply.

In comparison to previous studies (Javeed and Lefen 2019; Dash et al. 2018) based on the aforementioned findings, ensuring adequate energy is not enough as per recent study findings. This is one of the major disagreements of this research with previous study, and a key contribution in theory and practice.

As the aim stress an ecologically friendly energy production method and sources. In other words, energy sources are clean, not harming the environment . Most energy now originates from fossil fuel burning. Fossil fuel burning process produces carbon emissions and other greenhouse gases, which are environmentally harmful and contribute to climate change . Therefore, ensuring energy security while also preserving the environment is essential. Accordingly, the goals of this study are to assess energy efficiency and sustainability at regional and national level and evaluate and propose green and sustainable energy routes for energy security and climate change mitigation, and energy reforms for Asia Pacific are linked to energy efficiency.

The imperative to integrate sustainable economic system expansion to attaining growth-related aims of nations in the forthcoming 10 years has necessitated examining the correlation between RE and economic system expansion which gained traction in the scholarly world nowadays. Irrespective of the appeal to research into this area, scientific analysis substantiated varied findings (Sebri 2015). Additionally, several types of research have focused on one nation. Rafindadi and Ozturk (2017) and Maji (2015) apply a time series approach for examining the study. A shortcoming of one nation analysis approach is that it is limited by a minute population that decreases the strength of their unit root series evaluation and cointegration (Streimikiene and Kasperowicz 2016). In order to avert this situation in time series evaluation, the present research has applied a longitudinal unit root and longitudinal cointegration examination proposed by Maji et al. (2019), integrating the dual time series and cross-sectional data (Inglesi-Lotz 2016). Hence, longitudinal investigation approach application is applied to analyze the interconnection among RE and economic system expansion for sustainable development (Amri 2017; Koçak and Şarkgüneşi 2017). Regardless of variations in approaches, the population timeframe and longitudinal set of nation researched (Chang et al. 2015) found a dual directional correlation among EC and economic expansion.

The correlation among ecological, manufacturing composition, green financing, merchandise, corporate proprietorship, economic amalgamation, and market separation is currently discussed gaining prominence globally. Zhou et al. (2013), Ren et al. (2014), and Witt (2014) investigated the conduct of the fiscal governance and the public alongside variations in the ecological worth, particularly the effect of fiscal devolution on the ecology (Rodriguez-Gonzalez et al. 2018; Lepitzki and Axsen 2018). This has been observed that fiscal devolution adds to advancing the ecology's worth via enhanced government spending and composition. Additionally, Wang et al. (2019) and Jia (2019) show that energy efficiencies through renewable electricity generation are associated with green financing. More so, an unspecified or non-important correlation between fiscal devolution and ecological emission is anticipated. (Chaudhary et al. 2015; Jebali et al. 2017). To sum up, one cannot say that fiscal devolution leads to an enhanced or decline in ecological worth, while vertical disequilibrium causes the missallotments of government resources. It is anticipated that the advanced stage of expansion of vertical fiscal disequilibrium, the superior the mis allotment of resources, and the shortfall of competence up to (Järlström et al. 2018) & (Guo et al. 2016). Correspondingly, the studies presumed that the green financing is generally unavoidable within the system of renewable electricity generation and energy efficiency.

Conclusion and policy implication

This research was performed to identify developed and developing countries' energy efficiency as a crucial element in renewable energy generation and maintaining energy efficiency in different sample economies. In recent years, the role of green financing has risen significantly, generating maximum clean and green energy through renewable energy sources and extending energy efficiency in energy systems at country level. Research on the energy efficiency in the provinces of these nations may offer a foundation for decision-making in the formulation of energy and environmental policies and policy reforms. Hence, our study concluded significant role of green financing on energy efficiency through higher renewable energy generation. Renewable energy development and policy implications presented in this research may assist the government overcome these obstacles to a seamless transition to renewable power.

The study contributed in many points. Energy efficiency in study 28 nations and their provinces still has lots of space to enhance energy efficiency, and production growth and CO_2 emission reduction still have promise. Result shows that energy efficiency in three main areas. These nations have substantial geographical variations, exhibiting a development pattern. The east-middle-west and eastern region efficiencies are greater than the central and western; moreover, the difference between them continues to grow. Combining energy efficiency with environmental energy in three areas is helpful in study. After reviewing the loss of efficiency caused by regulatory and environmental regulatory costs in 2014 for each province, it shows that most provinces have environmental regulatory costs and that their economic development depends primarily on environmental capacity with significant environmental costs for economic growth. Therefore, altering economic development mode and enhancing environmental quality is an essential need. Within a joint production framework of both favorable output (GDP) and unfavorable output (CO_2 and SO_2), as well as energy input (total energy consumption) and non-energy input (labor and capital stock), this study uses an envelope-based data set model to evaluate the total energy and environmental efficiency factor of 25 administrative regions and three of these countries. This research also uses DEA window analysis methods to evaluate efficiency on cross-sectional and data-varying data to compute efficiency score throughout the periods of study. And empirical findings indicate that these nations' eastern region has better energy and environmental efficiency than the center area, and the westward area's efficiency is lowest. The efficiency of all three sectors varies similarly, and typically, the energy and environmental efficiency of these nations improved somewhat from 2016 to 2020. The eastern region's energy and energy efficiency and environment do better than the middle and western regions. These nations enhance market reforms with lower-price future energy markets.

Differences in the three regions' efficiency may come from the economic development imbalance, not too much.

High energy and country-wide environmental efficiency may be induced by the economic growth style of these nations. Effective energy and environmental protection regulations established and implemented by government during the last decade, however, may have helped to improving energy and environmental efficiency. Electricity market reforms in Asia Pacific nations offer more precise data availability in various policy making periods, and greater energy efficiency provides stronger market changes. Indeed, a series of significant policy changes in these areas are currently underway and have produced tangible benefits. Energy prices have been modified since 2010, high-tech, less energy-intensive smartphone and mobile device manufacturing has increased export shares, and the importance of the economy's state sector has progressively decreased with private sector growth. In addition to this positive phenomenon, there is the current trend globally towards green and sustainable energy usage, which has a direct impact on APE's energy production agenda. Thus, investigating such avenues in upcoming research could more enhance the knowledge and practice. The main restriction was limited access to data. The authors believe that empirical data in this work encourages future scholars to investigate the connection between additional transmission indicators and energy efficiency.

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Data availability Data is publicly available at mentioned sources in data section. **Corresponding author :** Jing Lan (lanjinge@yahoo.com)

Declarations

Ethics approval and consent to participate We declare that we have no human participants, human data, or human issues.

Consent for publication We do not have any individual person's data in any form and we give consent for publication in true letter and spirit.

Competing interests The authors declare no competing interests.

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