Energy financing in COVID-19: how public supports can benefit?

Sajid Iqbal
KUBEAC, University of Management and Technology, Sialkot, Pakistan, and
Ahmad Raza Bilal
Faculty of Business, Sohar University, Sohar, Oman

Received 28 February 2021
Revised 18 May 2021
21 September 2021
Accepted 9 October 2021

Abstract

Purpose – The study aims to empirically estimate the role of public supports for energy efficiency financing and presents the way forward to mitigate the energy financing barriers that incurred during the COVID-19 crisis.

Design/methodology/approach – Using the G7 countries data, the study estimated the nexus between the constructs. Generalized method of moments (GMM) and conventional increasing-smoothing asymptotic of GMM are applied to justify the study findings. Wald econometric technique is also used to robust the results.

Findings – The study findings reported a consistent role of public support on energy efficiency financing indicators, during the COVID-19 crisis period. G7 countries raised funds around 17% through public supports for energy efficiency financing, and it raised 4% of per unit energy usage to GDP, accelerated 16% energy efficiency and 24% output of renewable energy sources, during COVID-19. By this, study findings warrant a maximum support from public offices, energy ministries and other allied departments for energy efficiency optimization.

Practical implications – The study presents multiple policy implications to enhance energy efficiency through different alternative sources, such as, on-bill financing, direct energy efficiency grant, guaranteed financial contracts for energy efficiency and energy efficiency credit lines. If suggested policy recommendations are applied effectively, this holds the potential to diminish the influence of the COVID-19 crisis and can probably uplift the energy efficiency financing during structural crisis.

Originality/value – The originality of the recent study exists in a novel framework of study topicality. Despite growing literature, the empirical discussion in the field of energy efficiency financing and COVID-19 is still shattered and less studied, which is contributed by this study.

Keywords Energy financing, Energy efficiency, COVID-19 crises, Public supports, G7 economies

Paper type Research paper

1. Introduction

Public supports, such as social and economic supports, are extensively expected by the energy sector and common public during the COVID-19 pandemic (Mofijur *et al.*, 2020; Iqbal *et al.*, 2021). The public supports aimed at increasing energy efficiency through energy financing do not reach their envisioned effects (Taghizadeh-Hesary and Yoshino, 2019; Park and Chung, 2021). There is a need to identify the role of public supports for energy efficiency finance during the COVID-19 pandemic, and present the policy guidelines for key stakeholders (Taghizadeh-Hesary and Yoshino, 2020), if suggested policy measures applied effectively, are expected to enhance energy efficiency during the crises periods (Li *et al.*, 2021a, b). However, this is the motivation of recent study.

Managing energy efficiency remained a serious concern during the COVID-19 outbreak (Amankwah-Amoah, 2020). Two main issues persisted during coronavirus outbreak around the world; first, health emergency and large-scale incubation of corona-positive patients, secondly decline in energy market due to unexpected drop in oil prices (Iqbal *et al.*, 2021). These issues subsequently reduced energy efficiency and led global economies toward a downturn (Yoshino *et al.*, 2021). Besides, energy efficiency is also affected by the climate change effects and advanced reactions of carbon emission during the pandemic (Alemzero *et al.*, 2021). The estimates showed that around 17% worldwide change is observed in climate

China Finance Review International
Vol. 12 No. 2, 2022
pp. 219-240

2044-1398
DOI 10.1108/CFRI-02-2021-0046

change under pandemic lockdown, and this change affected energy efficiency by around 32%. Extending to it, Burkle (2020) cited that carbon emission is expected to reduce in pandemic period, and there is a probability with 1.2% reductions in energy efficiency. Another study by Iqbal *et al.* (2021) revealed an 11% reduction in energy efficiency due to the structural impacts of the COVID-19 crisis on the energy sector. This indicates that the countries that are more populated and inclined toward oil production and consumption experienced a significant reduction in energy efficiency (Anh Tu *et al.*, 2021).

In current time, fast change in environment is up surging the need for sound and sustainable energy solutions (Mohsin *et al.*, 2021). Developing a green economy is the most influential way forward to it. For this, active public supports are prerequisite to sustain energy system and boost energy efficiency through green solutions (Taghizadeh-Hesary and Rasoulinezhad, 2020). More so, this also promotes economic resource mobility and economic growth under eco-environment openness (Didier *et al.*, 2021). Thus, the process of developing energy efficiency through public supports is an advanced accelerator speeding green growth up (Cheng *et al.*, 2020). Giving importance to public supports for energy efficiency during the COVID-19 pandemic is an indispensable topic of modern time (Silva *et al.*, 2020).

Therefore, a recent study sheds the light on the key antecedents of public supports involved in improving energy efficiency during pandemic crises (Corrocher and Cappa, 2020). Up till now, a detailed study on energy efficiency and public supports has not yet been conducted, while the detailed published documents of different energy-related departments and ministries of different countries have provided the baseline in developing the nexus between this study's constructs. Energy efficiency-related studies, such as Mohsin *et al.* (2021), Taghizadeh-Hesary and Yoshino (2020) and Streitferdt *et al.* (2017) also provided a theoretical support to design the theoretical framework testing the nexus between public supports and energy efficiency in crises period. Notably, around $2 trillion is expected to be invested through public supports for energy efficiency, pollution emission reduction and sustainable economic development, after the COVID-19 outbreak. More specifically, published sources declared that this huge amount of energy efficiency financing would be invested in renewable, clean and green energy projects and shall contribute to accelerate energy efficiency further (Taghizadeh-Hesary and Yoshino, 2020).

Interestingly, renewable energy sources hold an ample potential to sustain energy consumption patterns and maintain energy efficiency to a greater extent, but for this purpose, a sufficient amount of public support is needed to mitigate energy inefficiency often caused during the pandemic. For this purpose, International Energy Agency (IEA) suggested providing public support of around USD16 trillion in total, ranging from the financial year of 2015–2050. This suggestion for energy efficiency is aligned with the Paris goal agreement. However, public supports for energy efficiency in the energy sector are working at a very slow pace (Barbier, 2020). Considerably, the COVID-19 crisis cracked multiple economic, social and environmental issues just with one punch. Consequently, local governments are now facing economic hardship in raising funds for energy efficiency (Azhgaliyeva *et al.*, 2020). It has many reasons, such as more fossil fuel-based energy plants, high carbon emission rate (Karmaker *et al.*, 2020), structural effects of the pandemic, reduced oil and gas prices (Mathews *et al.*, 2010), long payback periods, low awareness and orientation toward green energy sources and investment unattractiveness (Rodríguez-Molina *et al.*, 2014).

The statistics of the 2018 fiscal year showed a 65% rise in energy-generation sources worldwide. This rise is more than two times from coal power and gas-related energy generation plants. Green financing strategies remained the key success factor behind this record growth in the energy sector around the globe that advanced energy efficiency around 230%. Despite all,

this growth rate and rise in energy efficiency failed to bear the crisis shocks like the COVID-19 outbreak. However, to sustain energy efficiency under crisis period, more prudent financing strategies under the umbrella of green finance are still needed (Iqbal *et al.*, 2021). For this, a recent study is an attempt with an alternative option signifying that public supports are a prerequisite for energy efficiency finance to mitigate adverse effects of crisis periods like a pandemic, and for this, national government must serve as a party to regulate energy efficiency mechanism with green financing and protect energy consumption-related public rights (Simsek and Urmee, 2020).

On this, how public supports can help to mitigate crisis impacts through energy efficiency finance is a hot favorite question of modern energy financing discussion (Jiang *et al.*, 2021). Besides the contribution of energy efficiency finance policies, previous studies presented the nexus of the COVID-19 outbreak with energy consumption (Iqbal *et al.*, 2021) and explained the region-wise importance of green financing for economic and environmental integration (Anh Tu *et al.*, 2021). Previous researcher's contributed well in proving green energy financing as an innovative, clean and green solution to meet the energy efficiency needs of modern trends. Considering the COVID-19 pandemic, it is time to present the way forward to suggest to the policymakers about the sustainability and efficiency of energy financing, for which, public supports are much necessary. This is because policymakers act as catalysts and perform a significant role to empower energy efficiency through energy efficiency financing as they are strong advocates of energy policy than any other stakeholders (Morton *et al.*, 2020).

By this, our study contributes by estimating the antecedents of public supports and its key role in accelerating energy efficiency financing under the COVID-19 pandemic. Illustrating the green financing strategies for energy efficiency development in G7 countries over the period of the pandemic, our study developed and used a data set of 1,276 energy efficiency financing inflows shown in 78 observations of G7 countries. The study is the pioneer to contribute in knowledge by presenting multiple theoretical verdicts of key themes such as energy efficiency financing, public supports and COVID-19 outbreak. This is the theoretical contribution of the recent study. The study also contributes by discussing the empirical findings and suggesting the way forward on how to control energy efficiency through fine energy financing and public supports under crisis conditions. These are the practical contributions of this research. The rest of the paper is organized as follows: Section 2 discusses the previous literature that how the energy efficiency of G7 countries is affected by the COVID-19 crisis and reconciles the notion of the public supports to develop a prudent response for energy efficiency financing. Section 3 presents the methodology. Section 4 discusses the study findings, and Section 5 concludes the study and presents the policy implications for energy efficiency financing.

2. Literature review

The global world has financed around $138bn during FY-2018 to increase energy efficiency and reducing the intensity of energy consumption by around 3% from fuel and gas power plants on a per annum basis (Thomas and Rosenow, 2020). Studies presented numerous advantages of energy efficiency financing in published form of literature (Wang *et al.*, 2020). Low-cost programs provide grid benefits through infrastructure investment deferral associated with reduced congestion, reduced peak load and an overall reduction of electricity demand (Groppi *et al.*, 2021). Considering renewable energy sources and their growth mechanism through green energy financing (Taghizadeh-Hesary and Yoshino, 2020), the advantages of energy efficiency for potential consumers indicate progress in leisure and well-being, financial savings, and better electricity utility services, promoting economic growth (Sun *et al.*, 2021). After recognizing the extensive benefits of energy efficiency, many countries are using green financing solutions for

energy sustainability and development (Usman *et al.*, 2021). For three decades, the United Nations, China, Canada and Italy made significant development in making the energy sector efficient with net household energy consumption (Mandych *et al.*, 2020).

The G7 economies (e.g. Italy, France, Germany, Japan, Canada, USA and the United Kingdom) are the largest energy-consuming nations and developing their energy production and consumption system with more innovative and renewable solutions (Shahbaz *et al.*, 2020). Ironically, the COVID-19 pandemic hit a massive shock to the energy system of these countries and altered energy consumption patterns, returns of energy sectors and efficiency (Workie *et al.*, 2020). To mitigate such COVID-19 effects, public supports, such as economic supports, are essential for energy efficiency management. After COVID-19, the energy sector of G7 countries has become largely vulnerable and dedicated multiple energy shocks (Wang and Wang, 2020). Subsequently, the global oil price plunge in mid-2020 crashed the oil supply system, energy production and consumption and efficiency around the world (Okoh, 2021; Sun *et al.*, 2020). This is one of the great examples of the periodic effects of COVID-19 on energy efficiency. However, to mitigate such structural impacts of this crisis and for better energy efficiency, public supports are highly needed in all G7 countries. Before the pandemic, the energy efficiency system of G7 nations was 16% more efficient than the normal efficiency level through green financing and without public supports. After the pandemic, the energy efficiency system shown a 9% diminishes in energy efficiency. This shows a clear indication that green financing from private sources for energy efficiency is not a prudent solution during a crisis period (Sebitosi, 2008). So, to crack the energy efficiency and energy efficiency financing puzzle, there is a need for some public level contribution through public supports (Saleem *et al.*, 2020).

In response to energy efficiency under pandemic, the energy regulatory authorities and the national governments of G7 countries are planning to launch public support relief system (Barbier, 2020). On this, the newly elected US President – Mr. Joe Biden – also presented a five-point agenda for energy efficiency through energy efficiency financing with a resilient public support system. It includes:

(1) more further a faster in energy efficiency,

(2) use innovative energy solutions and achieve zero growth in carbon emission with strong legislative system,

(3) initiate urgent and additional actions for clean energy, climate change and green gas emission,

(4) finance energy efficiency with $400bn for clean energy system in USA and speed up the energy transition and

(5) making environmental justice a topmost priority and account pollution emitters accountable to law.

This shows a mature and sensible response from a world-leading economy toward energy efficiency financing with sound governmental, economic and financial supports (Jiang and Tan, 2021). Similar energy efficiency is being initiated by the other G7 countries on a lower level (Bertoldi *et al.*, 2021). "*Thus, public supports are a worthwhile element for energy efficiency through the best possible financing approach to reduce volatility and sustain the momentum of energy efficiency*" (Mirtchev, 2021, p. 10). In contrast to it, an extensive lack of public supports during the COVID-19 crisis has dulled energy efficiency around the world, including G7 nations (Wang and Wang, 2020). According to the Berkeley Lab report, G7 countries predicted a rise in energy efficiency around 17% at a minimum and 90% maximum in the normal course of time. These estimated resulted spuriously due to

structural-imposed crisis of the COVID-19 pandemic (Lahchen *et al.*, 2020). However, having no solution for crisis period is the key challenge for energy efficiency. Historic studies focused on industrial financing in renewable energy systems through energy finance (Taghizadeh-Hesary and Yoshino, 2020), while the research presenting the nexus and way forward on public energy finance for energy efficiency with the role of public supports is very limited (Sun *et al.*, 2020). The studies of Simsek and Urmee (2020) revealed that energy financing is an imperative solution for capital flow to reassure an effective shift in energy efficiency. The modern rush and quest for energy efficiency solutions gained much attention from different angles, from which, public attention is now an advanced aspect that warrants inquiry (Iqbal *et al.*, 2021).

Considering this, the study came up with the argument that public supports are nevertheless a nonnegligible, moderate support system that may advance energy efficiency financing with proper economic and regulatory financial attention and adequate to enhance energy efficiency and energy security (Figure 1). Due to limited research on understanding the matter of public supports for energy efficiency financing in the pandemic period, recent research intends to operationalize the empirical model to infer the role of the public supports on energy efficiency financing and to guide way forward for a better control against crisis like a pandemic in future. The study inference presented novel insights to the theorists and policymakers to consider substitute financing techniques under the umbrella of energy finance to lever persisting energy efficiency score up and put it on the growth track, specifically in the context of G7 countries.

Energy efficiency finance is extended for capital investment that needs multiple funding sources for energy production and consumption, energy efficiency and energy security (Sun *et al.*, 2020; Ali *et al.*, 2020). This financing is a kind of guaranteed investment with unlike attributes, explicitly, financial discrimination, energy financing costs and associated financing risks like operational risk, funding risk, distributional risk and market risk De Swaan, 2020). Notably, energy efficiency is widely dependent on energy financing policies; for this instance, public supports for energy financing have a certain role (Mohsin *et al.*, 2021). Moreover, the public supports also extend significance to gain energy efficiency through energy efficiency finance. Public supports are energy finance friendly and endorse sustainability in energy efficiency (Fresner *et al.*, 2017). Therefore, public supports are more domineering. Thus, following the notional principle of energy efficiency finance from Zhang *et al.* (2016), our study operationalizes the role of public supports in energy efficiency finance during the pandemic.

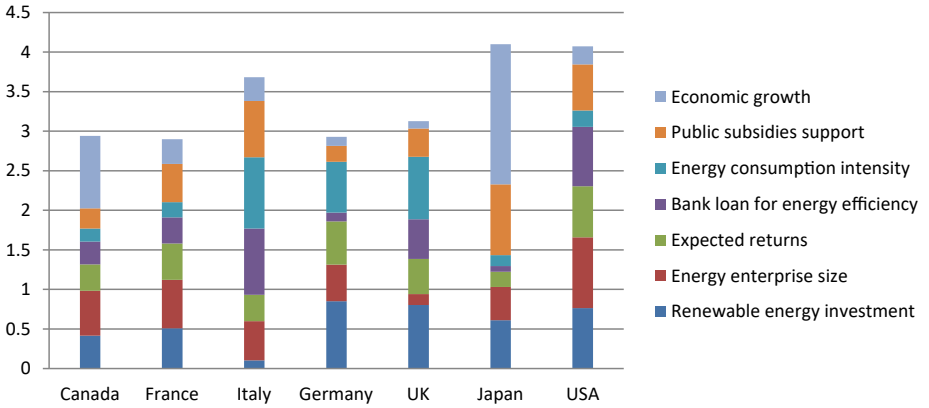

Figure 1.
Country-wise statistics about energy efficiency financing and public supports

Extending to it, San Ha *et al.* (2018) defined energy efficiency finance as, it is the cash paid by the government or any other energy regulatory authority to invest in energy-related fixed assets, intangible assets, and other long-term assets, to generate energy efficiency for the ultimate benefit of energy consumer satisfaction and national economic growth. Endorsing Zhang *et al.*'s (2016) findings, the role of public supports in energy efficiency finance is nonlinear, that is, a structural change of the COVID-19 pandemic up surging the extent when energy efficiency finance certainly arrive at a definite level. The study considered three constructs, specifically, energy consumption intensity, bank credit and economic development to measure public supports through governmental subsidies, as a threshold level of study analysis (Sun *et al.*, 2021).

3. Methodology

3.1 Study data and constructs

The study intends to estimate the verge of public supports for energy efficiency through energy financing. Many studies like Wang *et al.* (2017) suggested accelerating energy efficiency by investing in renewable energy sources. Therefore, multiple internal and external indicators of public supports are included in this study. These public supports indicators are derived from the basic notion of government subsidies. On this, studies extended the understanding that large economy size with adequate cash flows are suitably beneficial to finance for energy efficiency (Jiang *et al.*, 2003), just because these factors warrant a guarantee of favorable net present value (NPV), payback period and internal rate of return (IRR), from energy projects. Furthermore, previous findings and suggested to take proactively utilize financial risk control measures for energy efficiency. Therefore, considering large economies of G7 countries, recent research has taken renewable energy investment government subsidies, bank loans for energy financing as main variables and expected rate of return of energy projects and economic scales as control measures.

Energy efficiency, public supports in form of government subsidies and energy-related financing are the key indicators improving national economic growth; while, the data associated with it are acquired about G7 countries from different databases. Thus, study data include 110 renewable energy listed companies working in G7 countries; comprising, 37 wind energy companies, 15 geothermal companies, 18 renewable energy production enterprises and 40 solar energy firms. The study developed the data sheet about bank loans, expected income, economy size, energy efficiency investment and government subsidize for empirical estimation. The data for G7 countries were taken from different databases, such as, databank.worldbank.org, Fred.stlouisfed.org and data.worldbank.org, for the period of the COVID-19 outbreak ranging from November 2019 to February 2021 (monthly data) to execute empirical analysis.

3.2 Study model

Considering the theoretical underpinnings, the study anticipates estimating the role of public supports on energy efficiency finance is probable to be nonlinear, which is, the role of public financing may be a prudent solution for energy efficiency financing during crisis periods like the COVID-19 pandemic. Endorsing this a nonlinear regression models are applied and parametric estimates were pooled on different threshold values. We also estimated the threshold effect of the public supports to estimate the role of energy efficiency financing indicators such as bank credit, energy efficiency investment and economy size. This threshold estimation is originated from Hansen (1999) for more robust estimations. To harmonize the study constructs, heteroscedasticity and multicollinearity in data were removed and a natural logarithm was taken. The empirical form of study model is as follows:

$$LnPS_{it} = \beta_0 + \beta_{11} LnPS_{it}[EFI_{it} \le I_i] + \beta_{12} LnPS_{it} [EFI_{it} > I_i] + \beta_2 LNES_{it} + \beta_3 EE_{it} + \beta_4 RE_{it} + \epsilon_{it} \quad (1)$$

$$LnPS_{it} = \alpha_0 + \alpha_{11} LnPS_{it}[EFI_{it} \le c_i] + \alpha_{12} LnPS_{it} [BL_{it} > C_i] + \alpha_2 LNES_{it} + \alpha_3 EE_{it} + \alpha_4 RE_{it} + \epsilon_{it} \quad (2)$$

$$LnPS_{it} = \partial_0 + \partial_{11} LnPS_{it}[EFI_{it} \le c_i] + \partial_{12} LnPS_{it} [BL_{it} > C_i] + \partial_2 LNES_{it} + \partial_3 EE_{it} + \partial_4 RE_{it} + \varepsilon_{it} \quad (3)$$

where i is the year; t represents enterprise; $r1$, $c1$ and $k1$ are threshold values of the energy consumption intensity, bank credit and economic development level; INV: it is the renewable energy enterprises' investment; RD: it is government subsidies measuring the coefficients of the effect of public supports (e.g. government subsidies), for energy efficiency finance in terms of renewable energy investment, under the single threshold effect of energy consumption intensity, bank credit and economic development level, respectively. Moreover, β_{11}, β_{12}, α_{11}, α_{12}, and ∂_{11}, ∂_{12} are coefficients of effect of enterprise size, expected return and resource endowment on renewable energy investment with the energy consumption intensity, bank credit and economic development level as the threshold constructs.

3.3 Constructing public supports function

Public supports are basically the government supports for energy efficiency financing in the form of government subsidies during crisis period like structural-imposed crisis of COVID-19. Using combined effect functions and valued added functions with less elasticity in public supports suggested by Sato (1967), recent study estimated two extreme points of public support line, while, for middle input part Leontief function is used.

$$W_i = LM_i \cdot \left(\beta_i \cdot y_i^{Pi} + \lambda i \cdot N_i^{pi}\right)^{\frac{1}{Pi}} \quad (4)$$

$$\frac{PV_i}{PU_i} = \frac{Y_i}{\gamma_i} \cdot \left[\frac{n_i}{m_i}\right]^{1-pi} \quad (5)$$

$$PY_i \cdot \left(1 - \frac{tva_i}{1 + tva_i} \cdot leiv_i - it_i - dct_i\right) \cdot x_i = PU_i \cdot U_i + PV_i \cdot V_i \quad (6)$$

$$V_i = Av_i \cdot \left(Yi \cdot L_i^{Pi} - Y_{ki} \cdot K_i^{Pi}\right)^{\frac{1}{Pi}} \quad (7)$$

$$\frac{m}{r} = \frac{y_{li}}{y_{ki}} \cdot \left(\frac{K_i}{L_i}\right)^{1-pi} \quad (8)$$

$$Pv_i \cdot V_i = W \cdot L_i + r \cdot k_i \quad (9)$$

$$GX_{j \cdot i} = ut_{j \cdot i} \cdot U_i \quad (10)$$

$$PU_i = \sum Ut_{j \cdot i} \cdot PC_j \quad (11)$$

This is preconditioned to estimate government modules of public supports including federal and provincial level of subsidies for the understanding of public supports role on energy efficiency financing (*see* Eqn 12). From Eqs (4) to (11), combined effect function is constructed under consistent growth model (CGM).

$$PSs = svtf \cdot \sum EEI_i + \sum NES_j + \sum EE_j + \sum RE_J + shtf \cdot EEF + EFBL_0 \quad (12)$$

$$NGS = \sum EFI_J + (1 - svtf) \cdot \sum NES_i + (1 - shtf) \cdot EEF + EFBL_0 \quad (13)$$

$$EE_j \cdot EC_J = \vartheta_{fg} \cdot (EG + EEF_0 + EFBL_1 + ES_1) \quad (14)$$

$$REIf = REPI + NEP \quad (15)$$

$$PSsf = EEI + EEF + EFBL \quad (16)$$

The energy efficiency financing systems are aided with public supports covering, energy efficiency investments, energy-related bank loans, economy size and enterprise size by the local authorities of all G7 countries, shown in Eqn (13) onward. More so, renewable energy efficiency financing function is measured by using Eqn (15) and overall public support function is measured through Eqn (16). From Eqs (12) to (16) value added function is reported by following CGM assumption and parameters.

3.4 Empirical estimation strategy

Public support is less studied variable, and recent research is one of the early studies investigating it with energy financing techniques amid to the COVID-19 crisis. We found scant literature in this line. Primarily, public supports are tested with energy utility transmission (Heideier *et al.*, 2020), energy policy optimization (Safarzadeh *et al.*, 2020), energy efficiency initiatives (Lim and Brown, 2018), techno-economic perspectives of societies (Bukarica and Tomšić, 2017). We use following equation to estimate the connection between public supports and energy efficiency financing during the COVID-19 pandemic, where, i indicates the country (= 1,... i N) and t indicates the time period (= 1 ...) t.

$$Y_{it} = \beta_i Y_{it-1} + \beta EEF_{it} + X_{it} Y_{it} + \vartheta_{it} BL_{it} + l_i + \mu_i + \varepsilon_{it} \quad (17)$$

where Y_{it} indicates the public supports from i countries at t time, with a vector notation factor highlighting CGM function effects, that are key proxy measures of energy efficiency financing along with β and ϑ_{it} central limits. Here, are indicating G7 countries time specification an μ_i, ε_{it} error terms. It is reported strong limitations in ordinary least square method (OLS), which, this research framed in Eqs (1)–(3).

$$\Delta Y_{it} = \alpha_i \Delta Y_{it-1} + \beta \Delta EEF_{it} + X_{it} \Delta Y_{it} + \vartheta_{it} \Delta BL_{it} + \Delta l_i + \Delta \mu_i + \Delta \varepsilon_{it} \quad (18)$$

However, to reduce potential consequences of such limits, study endorsed Arellano and Bond (1991) and a typical difference approach entitled generalized method of moments (GMM) is used for empirical estimations of study framework. The motivation to use GMM is that is limits the endogeneity bias (Ullah *et al.*, 2018; Kitmura and Stutzer, 1997; Ferson and Foerster, 1994). Therefore, using GMM, Eqn (17) is converted into extended form as above.

Using GMM technique, it is imperative to operationalize one-way and two-way GMM methods to get confident, reliable and rigorous findings. This technique is good in developing the empirical estimation power between the constructs (Stock *et al.*, 2002). We developed weighted matrix for public supports and energy efficiency financing amid with uncertainty factor of the COVID-19 crisis. Past studies suggested considering uncertainty factors during empirical analysis for better outcome (Hansen, 1982). For this reason, Oxed-smoothing

asymptotics parameter of GMM is also considered to counter these COVID-19-related uncertainty factors in recent investigation. Moreover, long-run variance (LRV) of moments is also inferred (Sun and Huang, 2008). By this, study fulfilled all the assumptions of asymptotic theory to operationalize one-step GMM and two-step GMM methods to infer nexus between the constructs (Khan *et al.*, 2019). So, below given nonlinear Wald econometric method is fitted for GMM estimation and following conventional increasing-smoothing asymptotics for one-step and two-step GMM:

$$W_{1T} = \overset{d}{\Rightarrow} X_p^2\left(\left\|\Delta_1^{-1}\delta_0\right\|^2\right), W_{2T} = \overset{d}{\Rightarrow} X_p^2\left(\left\|\Delta_2^{-1}\delta_0\right\|^2\right)$$

$$T_{1T} = \overset{d}{\Rightarrow} N\left(\Delta_1^{-1}\delta_0, 1\right), T_{2T} = \overset{d}{\Rightarrow} N\left(\Delta_2^{-1}\delta_0, 1\right)$$

Following above measurement, we used following series when $\delta_0 = 0$

$$W_{1T}, W_{2T} = \overset{d}{\Rightarrow} X_p^2 \text{ and } T_{1T}\, T_{2T} = \overset{d}{\Rightarrow} N(0,1)$$

Hence, considering above measurements and estimation models of GMM, one-step and two-step estimators are asymptotically found normal and applied.

4. Results and discussion

4.1 Empirical findings

The study findings reported significant connectivity of public supports with energy efficiency financing. The empirical outcomes confirmed the established argument that a 17% rise in public support would better accelerate energy efficiency around 44% in crisis period like COVID-19, via good energy financing techniques. On these constructs, descriptive statistics are reported in Table 1. Financing and investing in renewable energy and/or green energy sources are widely suggested. Investing in clean and green energy sources through energy financing would not only boost energy efficiency but also give an additional support to mitigate climate change and environmental protection. However, the benefits of energy financing are multiple; one optimization of energy efficiency and the second is controlling environmental degradation.

As public supports are significant to better optimize energy financing; therefore, it is suggested to G7 countries to invest 15% of the energy financing budget in solar energy sources, 30% in wind energy sources, 10% in biomass energy sources and 10% in tidal energy sources to boost energy efficiency by adjusting effects of the COVID-19 pandemic (see Figure 1). For this, energy efficiency initiatives were introduced and suggested to take (Parnell and Larsen, 2005). These energy efficiency initiatives hold the strong potential to accelerate energy efficiency through energy financing (Karakosta *et al.*, 2021). From these initiatives, energy conversation system (ECS), environmental-energy protection design (EPD), energy-boosting codes (EBC) and green-rated energy assessment tool (GRAT) were

Variables	$\widetilde{X}$	Σ
Renewable energy investment	3.02	0.12
Energy enterprise size	2.79	0.91
Expected returns	4.34	12.8
Bank loans for energy efficiency	3.04	7.11
Energy consumption intensity	5.55	4.11
Government subsidies for support	0.46	0.62
Economic growth	0.38	0.19

Table 1.
Empirical description

found significantly contributing to the energy efficiency of India, China's belt and road initiative, East Asia and United Kingdom (Chandel *et al.*, 2016).

The study also considered these energy efficiency initiatives and reported the strength and weaknesses of G7 countries in terms of energy efficiency financing (see Table 2). Table 2 showed that the 8.5% possibility of growth by 2021 and around 17% growth prospect in G7 countries by 2026 (on a per annum basis). Notably, for all these growing trends, the supports by the public offices of each G7 country are a prerequisite in achieving energy efficiency through energy financing. Systematic support for energy efficiency was reduced due to coronavirus effects on G7 energy industries, powerhouses and economies. Alternatively, public supports were required; however, a rise in public supports is found by this research showing an increase in energy efficiency financing through energy subsidies over the period of the COVID-19 pandemic (e.g. November 2019 to February 2021), with public financing and investments.

The percentage of investment by the G7 countries for energy efficiency is also assessed by showing the percentages of energy demand, production and consumption patterns of G7 nations during the COVID-19 outbreak. The net public support for energy efficiency financing led to the growth of around 23.02% in energy imports, 468.95% in power consumption, 3.35% in alternative and nuclear power production, 70.66% in access of electricity to the urban population and 97.15% in access of electricity to the rural population during the COVID-19 pandemic. Thus, Figure 2 indicate nation-wise energy efficiency investment and indicator-wise scores of net energy efficiency financing through public supports provision by G7 countries in structural-imposed crisis of the COVID-19 outbreak. The findings showed a significant contribution of the public supports in energy financing gaining energy efficiency to a larger extent under crisis conditions. Undoubtedly, public

Variable	Canada	France	Italy	Germany	UK	Japan	USA
Renewable energy investment	0.417*	0.508*	0.104*	0.851*	0.804*	0.612	0.765*
Energy enterprise size	0.567*	0.613*	0.495*	0.463*	0.138*	0.419*	0.893*
Expected returns	0.333*	0.461*	0.332*	0.545*	0.444*	0.192*	0.646*
Bank loan for energy efficiency	0.288*	0.329*	0.838*	0.111	0.501*	0.072*	0.751*
Energy consumption intensity	0.164*	0.191*	0.901*	0.643*	0.789	0.140*	0.206*
Public subsidies support	0.257*	0.485*	0.713*	0.202*	0.357*	0.804	0.584*
Economic growth	0.914	0.313	0.300*	0.115*	0.095*	1.77*	0.227*

Note(s): *5% level of significance on the basis of *p*-value

Table 2.
Public support and energy efficiency finance: full sample

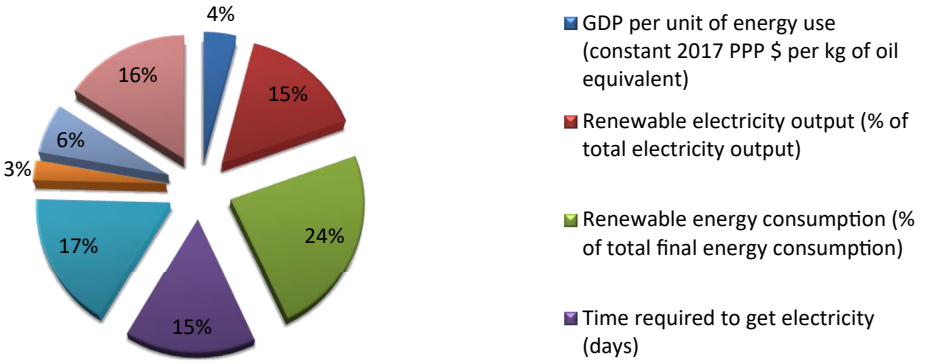

Figure 2.
Indicator-wise score of energy financing in G7 countries during COVID-19

supports are a significant efficiency booster for G7 countries tracking their energy sector on fastest growth with resilience and stability against the crisis period effects.

Considering the win-win situation, the significant rise of energy efficiency financing through public supports in G7 countries holds the potential of a 10.4% increase in energy sustainability by uplifting, solar energy and green energy sector till 2035 with a $7.1 trillion contribution in net GDP of G7 nations. Not only this but subsequently around 8.57% decrease in poverty rate is also estimated by the innovative contribution of energy efficiency financing, for which, public supports are proved as the best driver. A 56% of growth in renewable energy consumption was planned in Germany, 39% in Italy and 74% in Japan to enhance the capacity of the energy sector and to optimize energy efficiency. These percentages were also largely affected by the COVID-19 crisis, which were again uplifted by the proactive public support measures taken by the G7 countries, individually and collectively both. The energy performance index is vital tool presenting the effects of public supports on energy performance of G7 countries (see Table 3).

In G7 nations, now Germany and Italy can also be considered as booming energy-efficient economies after the COVID-19 crisis for the current decade (2021–2030). These countries are actively installing wind energy plants, solar power hubs and working to improve energy intensity ratio fitting with their contextual and socioeconomic conditions for energy conservation and production. On the other side, hydropower consumption is also important and most related energy efficiency indicator. Hydropower system usually shows less inefficiency, as these systems are purely in federal control in G7 context. In our sample of countries, the percentage of energy imported is more of less stable, even during the COVID-19 pandemic, and therefore, we do not expect it to have a strong role in determining the private finance in solar energy across sampled countries. The outcomes reported in Table 4 estimated

G7 countries	2013	2014	2015	2016	2017	2018	2019	2020
USA	0.64	0.35	0.64	0.66	0.45	0.77	0.55	0.77
UK	0.84	0.73	0.45	0.46	0.89	0.89	0.44	0.70
Japan	0.81	0.76	0.97	0.94	0.81	0.87	0.84	0.65
Italy	0.66	0.78	0.84	0.74	0.87	0.86	0.76	0.74
Germany	0.84	0.73	0.89	0.87	0.89	0.98	0.86	0.84
France	0.59	0.62	0.58	0.59	0.80	0.73	0.56	0.67
Canada	0.81	1	1	1	1	0.75	0.60	0.89

Table 3.
Energy efficiency performance score of G7 countries

	One step (I)	Two step (II)	One step (III)	Two step (IV)
Renewable energy investment	0.348* (0.002)	0.057* (0.005)	0.236* (0.001)	0.042* (0.026)
Energy enterprise size	0.011 (0.000)	0.431* (0.000)	0.171* (0.003)	0.269* (0.002)
Expected returns	0.044* (0.004)	0.034* (0.022)	0.078* (0.001)	0.045* (0.005)
Bank loan for energy efficiency	0.033* (0.006)	0.042* (0.004)	0.054* (0.000)	0.036* (0.000)
Energy consumption intensity	0.086 (0.006)	0.057* (0.037)	0.074 (0.056)	0.027 (0.021)
Public support through subsidy	0.818* (0.010)	0.756* (0.044)	0.285* (0.000)	0.333* (0.000)
Economic growth	0.134* (0.000)	0.186* (0.000)	0.155* (0.003)	0.207* (0.002)
Adjusted R^2	0.075		0.089	
Arellano-bond AR(1)		4.101 [0.000]		3.537 [0.000]
Arellano-bond AR(2)		0.376 [0.636]		0.881 [0.501]
Sargan test		204.711 [0.683]		288.709 [0.696]

Note(s): p-value in brackets and standard errors in parentheses; *p-value < 0.05

Table 4.
Estimating nexus between constructs through one-step and two-step GMM

the one-step and two-step findings of GMM estimators through asymptomatic variance design – as discussed in empirical estimation strategy. The findings of two-step GMM estimators highlighted that public supports remained a significant predictor of energy efficiency financing during the COVID-19 pandemic with ideal loading of the empirical estimates. By this, study findings are proved as significant through GMM.

According to one-step and two-step GMM estimation, the dependence of energy efficiency financing on public supports through a subsidy for energy efficiency is inferred. With the promising amount of endogeneity, the study estimated the empirical model with lagged-based empirical methods. Table 4 tabulated that indicators of energy efficiency, such as renewable energy investment, energy consumption intensity, bank credit, expected returns of energy industries and energy enterprise size, are significantly contributing to energy efficiency through public support of G7 countries. Notably, public support is measured by taking public subsidy support to the energy sector. Thus, study outcomes confirmed that high-energy investments, energy intensity, bank loans for energy efficiency, size and expected returns are induced by the public support given by G7 countries. Promisingly, this public support is aimed to mitigate the structural effects of the COVID-19 crisis to secure the energy efficiency outlook in the very next future of energy industries of the study sample. However, this supports is proved as significant and contributing well.

The study findings are aligned with Yang *et al.* (2019) confirming the role of government subsidies on energy investments that optimize energy efficiency through energy financing. The findings entail that the high volume of public support in the form of financial subsidy to the energy sector of developed economies like G7 countries accelerates energy efficiency and gives rise to economic growth. More so, the constructive part of control variables, such as energy-boosting codes, energy conservation, green-rated energy tools, and environmental-energy protection method supported the nexus between public supports and energy efficiency financing to develop the significant inference. The study found no empirical contradiction in the empirical role of control variables. By this, the significant role of control variables in study Eqn (17) and (18) specified that public supports during the COVID-19 pandemic are valuable to optimize energy efficiency financing; however, a vigilant and prudent consistency in actions is required for better outcomes.

4.2 Robustness of findings

Ranging the study data during the COVID-19 outbreak (2019–2021), our estimates confirmed the role of public supports on energy efficiency financing with multiple energy financing indicators and energy efficiency indicators that are reported in previous sections of study. Viewing the systematic effects of the COVID-19 crisis, the study findings proved these contingent effects that need more generalization. However, for empirical generalization, a robustness test is executed and reported in Table 5 showing a generalized change in the findings amid to the COVID-19 pandemic in international economies of G7 countries.

	Before COVID-19 outbreak		During COVID-19 outbreak	
	Public supports	EFF	Public supports	EFF
Public supports $_{t-1}$	0.444	0.512	2.313	4.887
Wald test	[0.27]*	[0.39]	[2.24]*	[3.99]**
p-value	(0.34)	(0.57)	(0.00)	(0.00)
EEF $_{t-1}$	3.78	2.05	3.75	4.78
Wald test	[2.01]	[2.73]	[4.24]*	[4.60]**
p-value	(0.25)	(0.45)	(0.00)	(0.00)

Note(s): *p-value for significance is *p < 0.05*

Table 5.
Robustness analysis

Relatively, the robustness findings are indicating in Table 4 that public supports before the COVID-19 pandemic was insignificant and discouraged the energy efficiency financing. On the other side, the role of public support is found as robust on energy efficiency financing during the COVID-19 pandemic. Amid to the COVID-19 outbreak, large-scale efficiency in energy system was required, and for this, energy financing through public supports is a key source. Thus, coefficient of public supports for energy efficiency financing is reported less in before the COVID-19 pandemic and high under the period of the COVID-19 pandemic. Hence, Table 4 confirmed the study findings through robustness analysis that public supports are a significant tool for optimization of energy efficiency financing in crisis periods like COVID-19 outbreak.

To enhance public supports Forrester and Remaes (2020) suggested diminishing energy coverage gap. On this, the data from the G7 countries 2012–2016 American Community Survey (ACS) 5-year estimates, generally representative of the time span of Michigan Saves' loans, were used to identify the number of households in the 17 income bands sectioned out by the Census Bureau. To define the coverage gap, this paper considers household incomes greater than 200% FPL (to be consistent with Michigan WAP criteria), but without disposable income to pay for EE upgrades upfront. To determine which households met the income qualification for WAP, we used county-level data from Fisher, Sheehan, and Colton's Home Energy Affordability Gap model for 2016 which details the number of households below 200% of FPL for each county in the USA. The mean density of households below 200% FPL across Michigan's 83 counties was 38.28% with a range of 17.3–51.7%.

4.3 Discussion on findings

The COVID-19 outbreak extended the economic crises around the world and this structural-enacted crisis diminished investment in the renewable energy system and compromised energy efficiency to a greater extent. In singular reality, energy efficiency is not sufficient to meet the requirements of International Energy organization estimates and global sustainability goals. More so, due to the COVID-19 crisis, the international energy markets also failed badly in the provision of a solution for energy efficiency optimization under crisis conditions. However, considering the importance of the COVID-19 outbreak in the context of energy efficiency, our study aimed to provide the solution to the global world on energy efficiency sustainability in crisis period. For this, the study came up with an advanced explanation to optimize energy efficiency financing through public supports in the form of energy efficiency subsidy and justified empirically that the active pubic supports enhance energy efficiency through energy financing.

The published studies on energy efficiency financing for G7 countries are scant, and there is a need for public support for financing to accelerate energy efficiency and encouraging energy sustainability. The current consideration of energy efficiency financing literature warrants the demand for the public supports the provision, including the special issue of *China Finance Review International*. Thus, there is a need to consider the six principles for energy financing especially for crisis periods like the COVID-19 outbreak. These principles include intergovernmental financial support for energy efficiency, financial resilience system, good energy efficiency governance system, spatial equity and public support affordability. Such energy financing principles optimize energy efficiency and strengthen energy financing justices. Green banks and community development financial institutions (CDFIs) are well-positioned to play this role, having already expanded access and mobilized private capital by utilizing public funds to create loan loss reserves, credit enhancements and other tools to lower the cost of capital.

The findings also highlighted that a rise in energy efficiency financing also accelerates economic growth and diminishes climate change-related issues. It is being found that

extension of public supports can enhance achievements of energy efficiency through energy financing and boosting public supports, for this reason, is much critical in G7 countries. Thus, the role of public supports is not similar for the energy sector and energy financing of all G7 countries. It is empirically obvious that the public supports for energy efficiency financing affects G7 countries more prudently in the period of COVID-19 and indicates an optimistic trend for energy efficiency optimization. But the role of energy–technology transformation for energy efficiency is appealing narrow and negative for the very starting period of technological advancement.

More precisely, the study highlighted that public economic policies for public supports are mostly based on economy-based instruments dominantly suggested by Forrester and Remaes (2020) and Yang *et al.* (2020) in comparison to any other form of direct private investment, public–private investment or any other public support for energy efficiency financing (Iqbal *et al.*, 2021; Li *et al.*, 2021; Tan *et al.*, 2019). The study results show that the G7 countries are more inclined to utilize public supports for energy financing (Taghizadeh-Hesary and Yoshino, 2019), mainly working to develop the environment to develop the settings for energy efficiency financing and not directly investing in renewable energy sources through public investments (Mohsin *et al.*, 2021).

There is no use in having huge assets if you cannot use them effectively. The ability to spend, innovate and expand energy efficiency creates employment opportunities, as well as energy, allowing societies to move from impoverished to prosperous, with people from poor to equitable and from behind to ahead. Its World Bank's agenda to make sure all people, anywhere, have access to accessible, safe, and renewable and efficient energy resources to combat energy demands and climate change. While the World Bank's mission is very clear and simple: ending hunger and increasing mutual wealth are at risk, achieving SD7 would require bold actions from governments, citizens, civil society and the private sector around the world.

The World Bank is focused on practical and realistic methods to delivering safe and sustainable energy to the world, as well as providing countries with technologies that suit their unique situations. It has also organized and promoted private sector participation in electricity access programs, specifically including micro grids and self-sustainable business models.

For the past five years, World Bank has allocated $6.2bn for access to clean energy projects, which just finished with FY19 allocations of $1.7bn. During the past three years, we have assisted developing nations to hook up 30 million fresh energy supplies to their customers. Africa is in the amount of over $1bn in the last two years. World bank has just completed projects to include mini grids and stand-alone networks in the region of $1bn. Currently, the World Bank has loan programs aimed at improving the cleanliness and energy availability of 5.7 million households that total $387m in 24 countries with which it has currently funded about 23.6 million citizens to date. Recognizing that electricity from renewables and sustainability are fundamental in growth, we have invested more than $9.4bn in that area over five years to support sustainable and energy-efficient development. This is great contribution by the side of World Bank for energy efficiency through energy financing.

5. Conclusion and policy implications

Considering the issue of energy efficiency due to COVID-19 in modern times, an advanced understanding is provided by this research on the subject matter about how energy efficiency financing through public supports during the COVID-19 crisis inevitable. The study especially contributed theoretically, empirically and policy-wise by dealing with novel, energy-economic, energy-financing and time-bound problems of energy efficiency financing under the COVID-19 outbreak. For this purpose, recent unlocked the association between

energy efficiency financing and public supports and presented the policy measures based on the COVID-19 crisis period. Conclusively, the study presented an optimal design for energy efficiency financing schemes suggesting a way forward for key stakeholders on access to energy and energy efficiency financing. Public support is the biggest driver supporting the energy sector, but realistically, it could be drastic to rely on this single source for energy efficiency financing all the time. However, it is high time to come up with alternative ways for energy efficiency financing. On this, study suggests the following policy implication for key stakeholders:

(1) Introduce energy efficiency financing fund (EEFF) in all the G7 countries. The intent of this fund should be solely dedicated to supporting the energy sector for energy efficiency in crisis periods or in the time of any other structural financial requirement. Interestingly, this fund would develop a resiliency factor in the energy sector and would secure energy efficiency failure. Apart from public financing, generating access to finance through private sources in the time of need is the main motivation to develop EEFF.

(2) The study included an implementation mechanism for energy efficient projects and invited all parties to follow it. This framework will help to analyze current energy financing programs and incorporate additional elements if needed.

This approach has outlined two goals to evaluate the performance of an energy efficient financing initiative: lowering energy consumption and ensuring that consumer operation continues after the program ends. While the first may be accomplished on its own through tailored services, it is much more common for them to be one-time or short-term solutions. Every apparently efficient initiative faces the risk that, if its funding is no longer sufficient,

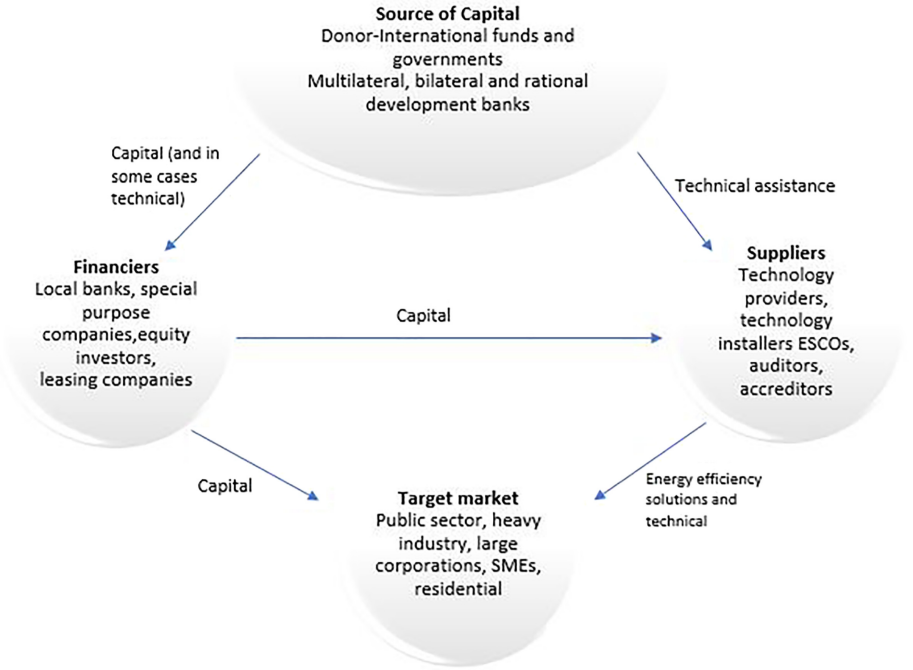

Figure 3.
Framework for the flow of energy efficiency financing

the supply and demand for financing will dwindle as well. There is a pressing need to promote long-term activity. Thus, the study suggests to use this framework for energy efficiency financing and must concentrate on the energy conservation issue in its entirety, as well as the legacy of its solution kit, in order to promote long-term improvement.

To expand the private sector economy, it is critical to realize that a competitive legacy would include attracting new entrants into the supply chain. However, the efficient usage of this framework would help to generate stable financing options for energy efficiency.

(1) Direct loans, direct grants and guaranteed financing for energy efficiency should also be introduced. Alternatively, these financing sources would reduce the burden on public supports under multiple financing conditions, such as high or low financing expensive or cheap financing options, compounded or discounted financing, depending upon the nature of requirements. Some other energy efficiency financing schemes like on-bill financing and bill-credit schemes should also be planned and introduced to support the end-users of the energy sector of G7 countries.

(2) Multiple issues related to guaranteed energy financing contracts, energy efficiency financing plans, on-bill financing, bill-credit financing can hinder the ultimate objective of energy efficiency. Possibly, social and economic difficulties to scale-up energy efficiency financing, lack of information, adverse economic support by the national government and less attractive financing options could be the main issues. Therefore, the study also suggests to policymakers to resolve these issues with their all due-diligence. The national governments also consider the matter to provide tax-rebate for energy efficiency sustainability in crisis conditions like coronavirus pandemic. This initiative can help G7 economics to maintain the energy efficiency scale, embed energy efficiency with sound financing support in terms of relief package and would help ignite energy markets.

5.1 Strategies to mitigate the barriers for energy efficiency financing

The research conducted by the Institute for Energy Efficiency (IEA) confirms that much of the money for energy conservation comes from private sources. If energy efficiency is described as increased output, then it is logical. The productivity of the investment owner typically absorbs the marginal costs within a limited period of time, such as less use. Over everything, energy conservation requires to be seen as a highly viable. A third consideration is that it would lead to greater expenditure in productivity in all the various energy sectors of the economy. The second step to assist potential and current owners in getting access to finance is working with landlords and lenders to remove financial and other obstacles to energy conservation. Considering these, the study suggests following points to mitigate potential barriers.

5.1.1 On-billing financing. Loans with the possibility of being paid off over time for energy efficiency projects are often referred to as on-bill lending or pay-back funding. Over time, the customer pays for their loan by adding payments to their regular bills. When it is accounted for, the expense to the consumer can be smaller than equivalent to the extra energy supplied by the optimization program. Good cash balance of customers was less likely to have to need some further financing. Financing which is structured as a debt is one where the customer bears the remaining amount of the balance may be referred to as off-bill financing. This offers the easiest most sensible ways to attract energy managers to assist in the energy savings efforts.

5.1.2 Diminishing transection costs and partial provision of guaranteed loans for energy efficiency. These methods will also better optimize energy efficiency of G7 countries and other regions.

5.1.3 Developing micro energy financing schemes. Energy efficiency investments tend to be smaller, offer better returns and provide quicker repayment than typical infrastructure investments. However, the small project size may negatively affect an owner's investment decision. Even though efficiency investments offer very competitive returns, they are often overlooked in favor of larger, revenue-generating production investments. A key challenge within organizations is motivating senior managers to view efficiency investments as a strategic priority that supports profitability, growth and sustainability.

5.2 Escalating economic recovery through public supports for energy efficiency financing

Although in the prepandemic era, the world was not on the track to achieve sustainable energy efficiency, now it has become even more challenging. This means that we should redouble our efforts and seek novel approaches to bring reliable, affordable and cleaner energy to all. For achieving SDG 7, implementation of energy trilemma can prove to be a game changer. Therefore, public supports are suggested as a supportive option. The energy trilemma addresses key dimensions – energy security, energy efficiency and environmental sustainability – necessary to achieve SDG 7 and build equitable, sustainable and more resilient economies in the post-COVID-19 world. Thus, an energy trilemma based on study framework is presented which is less studied and used to prioritize the energy efficiency financing. More supportively, active and consistent public supports, maximum energy efficiency financing can also speedup economic recovery – for which, following measures are suggested to align and implement.

(1) Gradual and stage-wise public support to energy efficiency and reopening of energy financing support system can boost economic recovery of G7 nations.

(2) The volume of public supports and timing for reopening would matter the most for the economic recovery in the context of G7 countries.

(3) Trust on public supports by the key stakeholders of energy sector and public perception about reopening of energy financing support system could also be significant drivers in signifying economic recovery system.

These suggestions of recent study hold important policy implications for the second wave of the COVID-19 pandemic that is currently sweeping in G7 countries and other parts of the world. Given the "pandemic fatigue" and growing public exhaustion and frustration with restrictions, public officials in many countries have been more reluctant to introduce strict interventions this time, fearing their economic impact. As the second wave of the pandemic worsened, they quickly found themselves with few other options. When the G7 countries start to reopen for the second time, our results and such suggestion could enhance gradual and transparent reopening of energy markets and can also increasing the chances of a faster economic recovery.

5.3 Future research directions

Energy efficiency financing is a popular subject in today's world. Several other issues remain unanswered in this context. We invite other researchers and upcoming scholars to continue their study in this topicality. However, we suggest to researchers to extend the knowledge by addressing and answering the following questions.

(1) What are the energy efficiency financing constraints and how they impact on energy efficiency during the COVID-19 period?

(2) How tight financing condition during crisis periods, like the COVID-19 outbreak, raise the cost of energy efficiency financing?

(3) Does energy efficiency financing matters for environmental efficiency or not?

(4) What would be the matter of energy efficiency financing in the post-COVID world?

(5) How to reform energy subsidies in the COVID-19 crisis to maintain efficiency of energy sector and other allied energy projects?

Accordingly, the answers to these questions would serve as the best possible solutions to enhance the bright side of energy efficiency.

References

Alemzero, D.A., Iqbal, N., Iqbal, S., Mohsin, M., Chukwuma, N.J. and Shah, B.A. (2021), "Assessing the perceived impact of exploration and production of hydrocarbons on households perspective of environmental regulation in Ghana", *Environmental Science and Pollution Research*, Vol. 28 No. 5, pp. 5359-5371.

Ali, S.H., Svobodova, K., Everingham, J.A. and Altingoz, M. (2020), "Climate policy paralysis in Australia: energy security, energy poverty and jobs", *Energies*, Vol. 13 No. 18, p. 4894.

Amankwah-Amoah, J. (2020), "Stepping up and stepping out of COVID-19: new challenges for environmental sustainability policies in the global airline industry", *Journal of Cleaner Production*, Vol. 271, p. 123000.

Anh Tu, C., Chien, F., Hussein, M.A., Ramli Mm, Y., Psi Mm, M.S.S., Iqbal, S. and Bilal, A.R. (2021), "Estimating role of green financing on energy security, economic and environmental integration of BRI member countries", *The Singapore Economic Review*.

Azhgaliyeva, D., Kapoor, A. and Liu, Y. (2020), "Green bonds for financing renewable energy and energy efficiency in South-East Asia: a review of policies", *Journal of Sustainable Finance and Investment*, Vol. 10 No. 2, pp. 113-140.

Barbier, E.B. (2020), "Greening the post-pandemic recovery in the G20", *Environmental and Resource Economics*, Vol. 76 No. 4, pp. 685-703.

Bertoldi, P., Economidou, M., Palermo, V., Boza-Kiss, B. and Todeschi, V. (2021), "How to finance energy renovation of residential buildings: review of current and emerging financing instruments in the EU", *Wiley Interdisciplinary Reviews: Energy and Environment*, Vol. 10 No. 1, p. e384.

Bukarica, V. and Tomšić, Ž. (2017), "Energy efficiency policy evaluation by moving from techno-economic towards whole society perspective on energy efficiency market", *Renewable and Sustainable Energy Reviews*, Vol. 70, pp. 968-975.

Burkle, F.M. (2020), "Political intrusions into the International Health Regulations Treaty and its impact on management of rapidly emerging zoonotic pandemics: what history tells us", *Prehospital and Disaster Medicine*, Vol. 35 No. 4, pp. 426-430.

Chandel, S.S., Sharma, A. and Marwaha, B.M. (2016), "Review of energy efficiency initiatives and regulations for residential buildings in India", *Renewable and Sustainable Energy Reviews*, Vol. 54, pp. 1443-1458.

Cheng, Z., Li, L. and Liu, J. (2020), "Natural resource abundance, resource industry dependence and economic green growth in China", *Resources Policy*, Vol. 68, p. 101734.

Corrocher, N. and Cappa, E. (2020), "The role of public interventions in inducing private climate finance: an empirical analysis of the solar energy sector", *Energy Policy*, Vol. 147, p. 111787.

De Swaan, J.C. (2020), *Seeking Virtue in Finance: Contributing to Society in a Conflicted Industry*, Cambridge University Press.

Didier, T., Huneeus, F., Larrain, M. and Schmukler, S.L. (2021), "Financing firms in hibernation during the COVID-19 pandemic", *Journal of Financial Stability*, Vol. 53, p. 100837.

Ferson, W.E. and Foerster, S.R. (1994), "Finite sample properties of the generalized method of moments in tests of conditional asset pricing models", *Journal of Financial Economics*, Vol. 36 No. 1, pp. 29-55.

Forrester, S.P. and Reames, T.G. (2020), "Understanding the residential energy efficiency financing coverage gap and market potential", *Applied Energy*, Vol. 260, p. 114307.

Fresner, J., Morea, F., Krenn, C., Uson, J.A. and Tomasi, F. (2017), "Energy efficiency in small and medium enterprises: lessons learned from 280 energy audits across Europe", *Journal of Cleaner Production*, Vol. 142, pp. 1650-1660.

Groppi, D., Pfeifer, A., Garcia, D.A., Krajačić, G. and Duić, N. (2021), "A review on energy storage and demand side management solutions in smart energy islands", *Renewable and Sustainable Energy Reviews*, Vol. 135, p. 110183.

Hansen, L.P. (1982), "Large sample properties of generalized method of moments estimators", *Econometrica: Journal of the Econometric Society*, pp. 1029-1054.

Hansen, B.E. (1999), "Threshold effects in non-dynamic panels: estimation, testing, and inference", *Journal of Econometrics*, Vol. 93 No. 2, pp. 345-368.

Heideier, R., Bajay, S.V., Jannuzzi, G.M., Gomes, R.D., Guanais, L., Ribeiro, I. and Paccola, A. (2020), "Impacts of photovoltaic distributed generation and energy efficiency measures on the electricity market of three representative Brazilian distribution utilities", *Energy for Sustainable Development*, Vol. 54, pp. 60-71.

Iqbal, S., Bilal, A.R., Nurunnabi, M., Iqbal, W., Alfakhri, Y. and Iqbal, N. (2021), "It is time to control the worst: testing COVID-19 outbreak, energy consumption and CO_2 emission", *Environmental Science and Pollution Research*, Vol. 28 No. 15, pp. 19008-19020.

Jiang, Q. and Tan, Q. (2021), "National environmental audit and improvement of regional energy efficiency from the perspective of institution and development differences", *Energy*, Vol. 217, p. 119337.

Jiang, Y., Lee, A., Chen, J., Ruta, V., Cadene, M., Chait, B.T. and MacKinnon, R. (2003), "X-ray structure of a voltage-dependent K+ channel", *Nature*, Vol. 423 No. 6935, pp. 33-41.

Jiang, P., Van Fan, Y. and Klemeš, J.J. (2021), *Impacts of COVID-19 on Energy Demand and Consumption: Challenges, Lessons and Emerging Opportunities*, Applied Energy, p. 116441.

Karakosta, C., Papapostolou, A., Vasileiou, G. and Psarras, J. (2021), "Financial schemes for energy efficiency projects: lessons learnt from in-country demonstrations", *Energy Services Fundamentals and Financing*, Academic Press, pp. 55-78.

Karmaker, A.K., Rahman, M.M., Hossain, M.A. and Ahmed, M.R. (2020), "Exploration and corrective measures of greenhouse gas emission from fossil fuel power stations for Bangladesh", *Journal of Cleaner Production*, Vol. 244, p. 118645.

Khan, H.U.R., Islam, T., Yousaf, S.U., Zaman, K., Shoukry, A.M., Sharkawy, M.A. and Hishan, S.S. (2019), "The impact of financial development indicators on natural resource markets: evidence from two-step GMM estimator", *Resources Policy*, Vol. 62, pp. 240-255.

Kitamura, Y. and Stutzer, M. (1997), "An information-theoretic alternative to generalized method of moments estimation", *Econometrica: Journal of the Econometric Society*, pp. 861-874.

Lahcen, B., Brusselaers, J., Vrancken, K., Dams, Y., Paes, C.D.S., Eyckmans, J. and Rousseau, S. (2020), "Green recovery policies for the COVID-19 crisis: modelling the Impact on the economy and greenhouse gas emissions", *Environmental and Resource Economics*, Vol. 76 No. 4, pp. 731-750.

Li, W., Chien, F., Hsu, C.C., Zhang, Y., Nawaz, M.A., Iqbal, S. and Mohsin, M. (2021a), "Nexus between energy poverty and energy efficiency: estimating the long-run dynamics", *Resources Policy*, Vol. 72, p. 102063.

Li, W., Chien, F., Ngo, Q.T., Nguyen, T.D., Iqbal, S. and Bilal, A.R. (2021b), "Vertical financial disparity, energy prices and emission reduction: empirical insights from Pakistan", *Journal of Environmental Management*, Vol. 294, p. 112946.

Lim, T. and Bowen, W.M. (2018), "Determinants and evaluation of local energy-efficiency initiatives from the American Recovery and Reinvestment Act", *Review of Policy Research*, Vol. 35 No. 2, pp. 238-257.

Mandych, O., Mykytas, A., Melnyk, M., Girzheva, O. and Kalinichenko, S. (2020), "Financial condition of the development of the market of renewable energy sources", *Renewable Energy Sources: Engineering, Technology, Innovation*, Springer, Cham, pp. 939-951.

Mathews, J.A., Kidney, S., Mallon, K. and Hughes, M. (2010), "Mobilizing private finance to drive an energy industrial revolution", *Energy Policy*, Vol. 38 No. 7, pp. 3263-3265.

Mirtchev, A.V. (2021), *The Prologue: the Alternative Energy Megatrend in the Age of Great Power Competition*, Post Hill Press.

Mofijur, M., Fattah, I.R., Alam, M.A., Islam, A.S., Ong, H.C., Rahman, S.A. and Mahlia, T.M.I. (2020), "Impact of COVID-19 on the social, economic, environmental and energy domains: lessons learnt from a global pandemic", *Sustainable Production and Consumption*.

Mohsin, M., Hanif, I., Taghizadeh-Hesary, F., Abbas, Q. and Iqbal, W. (2021), "Nexus between energy efficiency and electricity reforms: a DEA-based way forward for clean power development", *Energy Policy*, Vol. 149, p. 112052.

Morton, A., Reeves, A., Bull, R. and Preston, S. (2020), "Empowering and Engaging European building users for energy efficiency", *Energy Research and Social Science*, Vol. 70, p. 101772.

Okoh, A.S. (2021), "Political economy of fossil fuel exit", *Oil Mortality in Post-Fossil Fuel Era Nigeria*, Springer, Cham, pp. 47-88.

Park, J. and Chung, E. (2021), "Learning from past pandemic governance: early response and Public-Private Partnerships in testing of COVID-19 in South Korea", *World Development*, Vol. 137, p. 105198.

Parnell, R. and Larsen, O.P. (2005), "Informing the development of domestic energy efficiency initiatives: an everyday householder-centered framework", *Environment and Behavior*, Vol. 37 No. 6, pp. 787-807.

Rodríguez-Molina, J., Martínez-Núñez, M., Martínez, J.F. and Pérez-Aguiar, W. (2014), "Business models in the smart grid: challenges, opportunities and proposals for prosumer profitability", *Energies*, Vol. 7 No. 9, pp. 6142-6171.

Safarzadeh, S., Rasti-Barzoki, M. and Hejazi, S.R. (2020), "A review of optimal energy policy instruments on industrial energy efficiency programs, rebound effects, and government policies", *Energy Policy*, Vol. 139, p. 111342.

Saleem, H., Khan, M.B. and Shabbir, M.S. (2020), "The role of financial development, energy demand, and technological change in environmental sustainability agenda: evidence from selected Asian countries", *Environmental Science and Pollution Research*, Vol. 27 No. 5, pp. 5266-5280.

San Ha, N., Lu, G. and Xiang, X. (2018), "High energy absorption efficiency of thin-walled conical corrugation tubes mimicking coconut tree configuration", *International Journal of Mechanical Sciences*, Vol. 148, pp. 409-421.

Sato, K. (1967), "A two-level constant-elasticity-of-substitution production function", *The Review of Economic Studies*, Vol. 34 No. 2, pp. 201-218.

Sebitosi, A.B. (2008), "Energy efficiency, security of supply and the environment in South Africa: moving beyond the strategy documents", *Energy*, Vol. 33 No. 11, pp. 1591-1596.

Shahbaz, M., Raghutla, C., Chittedi, K.R., Jiao, Z. and Vo, X.V. (2020), "The effect of renewable energy consumption on economic growth: evidence from the renewable energy country attractive index", *Energy*, Vol. 207, p. 118162.

Silva, A.L.P., Prata, J.C., Walker, T.R., Campos, D., Duarte, A.C., Soares, A.M. and Rocha-Santos, T. (2020), "Rethinking and optimising plastic waste management under COVID-19 pandemic: policy solutions based on redesign and reduction of single-use plastics and personal protective equipment", *Science of the Total Environment*, Vol. 742, p. 140565.

Simsek, Y. and Urmee, T. (2020), "Opportunities and challenges of energy service companies to promote energy efficiency programs in Indonesia", *Energy*, Vol. 205, p. 117603.

Stock, J.H., Wright, J.H. and Yogo, M. (2002), "A survey of weak instruments and weak identification in generalized method of moments", *Journal of Business and Economic Statistics*, Vol. 20 No. 4, pp. 518-529.

Streitferdt, V., Chirarattananon, S. and Du Pont, P. (2017), "Lessons learned from studying public initiatives to support energy efficiency finance in Thailand from 1992 to 2014", *Energy Efficiency*, Vol. 10 No. 4, pp. 905-923.

Sun, H.P. and Huang, Z.H. (2008), "Games between local governments in regional industrial transfer", *Journal of Guizhou College of Finance and Economics*, Vol. 3.

Sun, H., Kporsu, A.K., Taghizadeh-Hesary, F. and Edziah, B.K. (2020), "Estimating environmental efficiency and convergence: 1980 to 2016", *Energy*, Vol. 208, p. 118224.

Sun, H., Edziah, B.K., Kporsu, A.K., Sarkodie, S.A. and Taghizadeh-Hesary, F. (2021), "Energy efficiency: the role of technological innovation and knowledge spillover", *Technological Forecasting and Social Change*, Vol. 167, p. 120659.

Taghizadeh-Hesary, F. and Rasoulinezhad, E. (2020), "Analyzing energy transition patterns in Asia: evidence from countries with different income levels", *Front. Energy Res*, Vol. 8, p. 162.

Taghizadeh-Hesary, F. and Yoshino, N. (2019), "The way to induce private participation in green finance and investment", *Finance Research Letters*, Vol. 31, pp. 98-103.

Taghizadeh-Hesary, F. and Yoshino, N. (2020), "Sustainable solutions for green financing and investment in renewable energy projects", *Energies*, Vol. 13 No. 4, p. 788.

Tan, R.R., Aviso, K.B. and Ng, D.K.S. (2019), "Optimization models for financing innovations in green energy technologies", *Renewable and Sustainable Energy Reviews*, Vol. 113, p. 109258.

Thomas, S. and Rosenow, J. (2020), "Drivers of increasing energy consumption in Europe and policy implications", *Energy Policy*, Vol. 137, p. 111108.

Ullah, S., Akhtar, P. and Zaefarian, G. (2018), "Dealing with endogeneity bias: the generalized method of moments (GMM) for panel data", *Industrial Marketing Management*, Vol. 71, pp. 69-78.

Usman, M., Makhdum, M.S.A. and Kousar, R. (2021), "Does financial inclusion, renewable and non-renewable energy utilization accelerate ecological footprints and economic growth? Fresh evidence from 15 highest emitting countries", *Sustainable Cities and Society*, Vol. 65, p. 102590.

Wang, Q. and Wang, S. (2020), "Preventing carbon emission retaliatory rebound post-COVID-19 requires expanding free trade and improving energy efficiency", *Science of The Total Environment*, Vol. 746, p. 141158.

Wang, X., Liu, C. and Hawkins, C.V. (2017), "Local government strategies for financing energy efficiency initiatives", *The American Review of Public Administration*, Vol. 47 No. 6, pp. 672-686.

Wang, F., Sun, X., Reiner, D.M. and Wu, M. (2020), "Changing trends of the elasticity of China's carbon emission intensity to industry structure and energy efficiency", *Energy Economics*, Vol. 86, p. 104679.

Workie, E., Mackolil, J., Nyika, J. and Ramadas, S. (202010001), "Deciphering the impact of COVID-19 pandemic on food security, agriculture, and livelihoods: a review of the evidence from developing countries", *Current Research in Environmental Sustainability*.

Yang, X., He, L., Xia, Y. and Chen, Y. (2019), "Effect of government subsidies on renewable energy investments: the threshold effect", *Energy Policy*, Vol. 132, pp. 156-166.

Yang, C., Gao, F. and Dong, M. (2020), "Energy efficiency modeling of integrated energy system in coastal areas", *Journal of Coastal Research*, Vol. 103 No. SI, pp. 995-1001.

Yoshino, N., Taghizadeh-Hesary, F. and Otsuka, M. (2021), "Covid-19 and optimal portfolio selection for investment in sustainable development goals", *Finance Research Letters*, Vol. 38, p. 101695.

Zhang, C., Wu, D., Sun, J., Sun, G., Luo, G. and Cong, J. (2016), "Energy-efficient CNN implementation on a deeply pipelined FPGA cluster", *Proceedings of the 2016 International Symposium on Low Power Electronics and Design*, pp. 326–331.

Further reading

Cin, R., Acuner, E. and Onaygil, S. (2021), "Analysis of energy efficiency obligation scheme implementation in Turkey", *Energy Efficiency*, Vol. 14 No. 1, pp. 1-21.

Eriksson, L. and Kjeang, A. (2021), "Local organization for promoting energy efficiency–reform of local energy advice service in Sweden", *Energy Efficiency*, Vol. 14 No. 1, pp. 1-16.

Lyulyov, O., Pimonenko, T., Kwilinski, A., Dzwigol, H., Dzwigol-Barosz, M., Pavlyk, V. and Barosz, P. (2021), "The impact of the government policy on the energy efficient gap: the evidence from Ukraine", *Energies*, Vol. 14 No. 2, p. 373.

Moerkerken, A., Duijndam, S., Blasch, J., van Beukering, P. and Smit, A. (2021), "Determinants of energy efficiency in the Dutch dairy sector: dilemmas for sustainability", *Journal of Cleaner Production*, p. 126095.

Murshed, M. (2020), "An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South Asia", *Environmental Science and Pollution Research*, Vol. 27 No. 29, pp. 36254-36281.

About the authors

Sajid Iqbal is Lecturer (Finance) at KUBEAC, University of Management and Technology, city campus, Sialkot – Pakistan. He is PhD (business administration) from Superior University, Lahore – Pakistan. He teaches financial management, investment and portfolio analysis, and international financial management. His areas of research are energy financing, COVID-19 crisis, substantial budget deficits and investment performance. He has published various research papers in good indexed journals, including Journal of environmental management (JEM), Resources policy Journal (RPJ), Environmental science and pollution research (ESPR), Singapore economic review (SER), Frontiers of energy research (FER), Energy efficiency journal (EEJ), Climate change economics (CCE), Global business review (GBR), and China finance review international (CFRI). Sajid Iqbal is the corresponding author and can be contacted at: sajidiqbal.edu@gmail.com

Dr Ahmad Raza Bilal is PhD (Management) from UTM, Malaysia. He is currently Associate Professor (Faculty of Business) at Sohar University Oman. He has vast experience of research in the areas of strategic management, entrepreneurial trainings, corporate governance, energy financing, and Business strategy and policy. Dr Bilal has authored various journal articles in renowned journals, such as Academy of Management (AOM), Chinese Management Studies (CMS), Career Development International (CDI), Organizational Change Management (OCM), The Journal of Risk Finance (JRF), Studies in Economics and Finance (SEF), Journal of environmental management (JEM), Environmental science and pollution research (ESPR), Singapore economic review (SER), Global business review (GBR), and China finance review international (CFRI).