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New Focus For Industrialization 4.0: Economic Growth Through Industrial Energy Management

Nazia Abdul Rehman[1]*, Muhammad Faisal Sultan[2] and Muhammad Asim[3]
1-Department of Economics, Federal Urdu University Karachi, Karachi, Pakistan
2-KASBIT, Karachi, Pakistan
3-KUBS-UoK, Karachi, Pakistan
*Corresponding Author: nzshakir@gmail.com

ABSTRACT

The purpose of this article is to understand and elaborate on the impact of energy management through the use of solar energy systems in the industrial sector over the economic growth of developing countries. This study is based on Pakistan where the concept is in the infancy stage. Therefore, the significance of the study has many folds as the study will not only reflect the contemporary use of solar panels in the industrial sector but also reflect vividly upon the implications of the concept regarding the eastern and developing markets. The study collected data from employees of the energy sector to test the claim with a non-probability sampling technique and analysis has been made through incorporating SMART-PLS. The findings of the study reflect that there is a definite association between the use of solar panels in the production sector on energy efficiency as well as the sustainable economic growth of the country. Hence the study is also beneficial for fostering research work as well as to optimize the policy formulation for the use of solar energy systems in the production sector of developing countries of the world.

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INTRODUCTION

Recent studies have consistently highlighted the need for sustainable development. In reality, survival depends entirely on sustainability. As a result, the study noted a shift in emphasis in favor of obtaining clean and sustainable energy (Abbas et al., 2020). That was generally accomplished in the past by using resources like chemical and electrical etc. However, the change in energy production and management has been threatened (Abbas et al., 2020), due to barriers from policy-makers, human resources, technology as well as economic conditions, etc. (Irfan et al., 2019). Energy efficiency, however, might not even be sought despite its effects on society and the economy. Thus, policy development and understanding are essential in this regard as proper policies associated with energy efficiency may reduce barriers in front of progress in this under-explored area (Cantore et al., 2016). Energy efficiency is extensively important for protecting society from climatic and environmental harms (Dołęga, 2019). Hence, there is a need to use measures like industrial energy management, home energy management, demand side management, smart metering, and integrated information and control technologies.

South Asia comprises 25% of the world's population. The annual growth rate of the population is likely to reach 1.9% per annum but the probable increase in demand for energy is expected to be raised by 7.4% to 7.6%. Pakistan is the second most populous country in South Asia but suffering from blackouts since independence (Abbas et al., 2020). The country is still fulfilling major of its energy needs by using hazardous fossil fuels not only for the economy but also for the environment (Irfan et al., 2019). However, the country is trying hard to attain energy through the utilization of renewable energy sources. Though on the other side energy demand in Pakistan is expected to be raised by 50% of the current energy supply by 2050. Therefore, there is a need to utilize the sun's energy and fulfil energy requirements through solar energy. Pakistan also falls behind several Asian countries in terms of per capita energy consumption. 51 million people are still living without electricity (Irfan et al., 2019).

Hence, there is a steep concern about the installation of solar systems to capitalize on massive periods of daylight (Abbas et al., 2018). Therefore, the country is trying to expand the use of renewable energy resources to increase the capacity of the national electricity grid. The country is planning to add 9700 MW of energy from renewable energy resources by 2030 (Irfan et al., 2019). The potential of renewable energy resources has also been recognized by the government of Pakistan and the government is trying to increase economic growth by focusing on a renewable energy mix (Jan et al., 2021).

There is always a significant relationship between energy consumption and economic growth (Aqeel & Butt, 2001; Shaari et al., 2013). Thus, the relationship has also been noticed by researchers and academicians. However, there is no clear evidence that may substantiate the relationship between energy efficiency and an increase in economic growth. The main obstacle to conducting studies on the relationship between energy efficiency and economic growth is a lack of data. Therefore, there is a need to investigate with reliable data that can clarify the picture (Lin & Zhou, 2022). Previously, surveys of the World Bank were used by Cantore et al. (2016), but the data only range from 2002 to 2004. Similarly, Jan et al. (2021), conducted a study based on hydro-power as the main source of renewable energy generation and declared that the unavailability of data associated with other forms of renewable energy is the main hindrance to the study. The study also mentioned the need for studies that may highlight the potential of other forms of renewable energy resources on economic growth. On the other side studies also reflected a significant linkage between the use of non-renewable energy resources and degradation of the environment and public health. Hence, various nations, especially developing countries are now getting focused on the use of renewable energy resources to increase economic growth as well as to protect against environmental degradation and public health (Fernando & Hor, 2017). Therefore, this study will be specially directed toward the exploration of the linkage between the use of solar panels in the production sector of Pakistan to assist policy making and to endorse the gap highlighted by Jan et al. (2021). This study is one of the premier ones to shed light on the use of solar panels for sustainable economic growth concerning Pakistan. Thus, the study is not only beneficial for students, academicians, and researchers but also a diverse set of stakeholders as well as policymakers for understanding the benefits of renewable energy from solar panels in the industrial sector of developing countries like Pakistan.

THEORETICAL FRAMEWORK

Pakistan has the massive potential of attaining energy efficiency through solar energy and in most parts of Sindh, Punjab and Baluchistan the sunshine remains brighter almost throughout the year. Hence the potential to capitalize on solar energy is much high. 45 MW to 83 MW of energy can be generated from an area of 100 m^2 (Adnan et al., 2012). Thus, factories may utilize renewable energy sources to gain energyefficiency (Dincer, 2011) as energy produced by renewable energy resources is much higher than non-renewable energy sources Goswami and Kreith (2007). A similar was found true for the use of solar energy as the use of solar panels in industries may foster the percentage of energy produced as well as quality (Mekhilef et al., 2011). Thus to increase economic growth the use

of solar energy might be preferred. Hence this study uses energy management through solar energy as the predictor variable, energy efficiency as the mediator, and sustainable economic growth of the country as the dependent variable.

The use of energy management via solar panels is valid as most of the prior studies e.g. Jan et al. (2021), indicated that data for other resources of renewable energy except hydro power was not available. In fact, to evident the impact of renewable energy on economic growth there is a need for reliable data (Lin & Zhou, 2022), as the other studies e.g., Cantore et al. (2016) are based on data that is from early 2000. Thus, the use of energy management from solar panels and its impact on energy efficiency in the production sector is a legitimate postulate to be evaluated. However, the use of the Internet of things is mandatory for the effective monitoring and management of energy achieved from solar energy (Katyarmal et al., 2018).

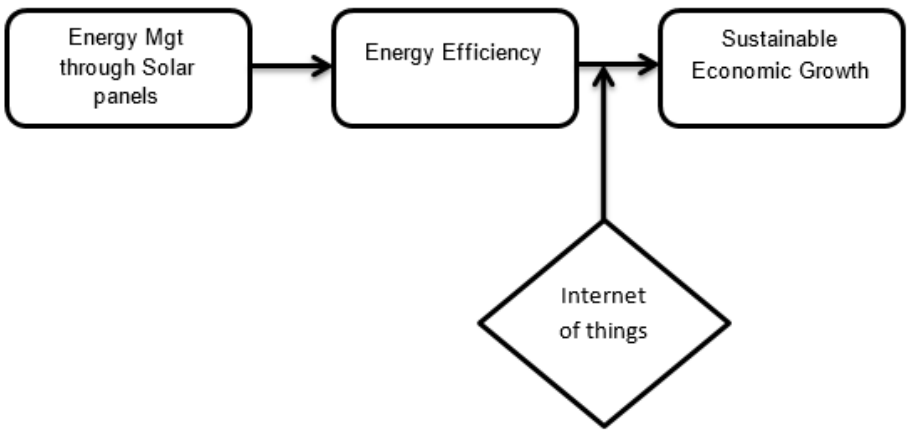

Figure 1: *Theoretical framework*

MAJOR RESEARCH QUESTIONS

Q 1: Why do solar panels have major significance for the industrial sector?

Q2: What is energy efficiency?

Q3: What is the significance of energy efficiency for the economy of Pakistan?

LITERATURE REVIEW

There is a direct linkage between the availability of electric energy to the entire population and the increase in economic growth of the country. Thus, efforts are made by several leading countries of South-East Asia to electrify all of their population but none of these became able to do that except Maldives. Thus, the concern is towards taking advantage of renewable energy resources to enhance power generation capabilities (Abbas et al., 2020). On the other side studies e.g., Lin and Zhou (2022), also reflected that using non-renewable energy resources is harmful to the environment as well as public health. Thus, overall the usage is not beneficial for sustainable economic growth and therefore instead of gas and oil, the surge is towards the use of renewable energy resources to lure with a series of benefits associated with energy and non-energy categories. On the other side, it has also been determined by the World Bank that energy efficiency is one of the major contributors to sustainable development goals. Moreover, turning towards renewable energy resources will provide us with a bright and low-carbon future. This may also foster the level of productivity. Renewable energy resources are found to be directly associated with an increase in per-unit productivity (Chen et al., 2022).

Energy Consumption and Economic Growth

World Bank has identified energy efficiency as a vital enabler for most of the SDGs. Moreover, boosting energy efficiency will provide a pathway to benefit the most vulnerable by enhancing their productive opportunities arising from the transition towards a low-carbon future. Renewable energy is directly linked to improvement in energy efficiency, which is an increase in productivity per unit of energy use (Chen et al., 2022).

The discussion over benefits was pretty well-established, only a few studies have addressed the possible negative impacts of the adoption of energy efficiency measures (Cagno et al., 2019). However, some of the past studies also highlighted a symmetric relationship between the use of energy resources and economic growth, and the relationship is majorly based on different stages of the economic cycle. Similarly, a study by Lee and Chang (2007) from Taiwan reflected U-shaped relationship exists between energy consumption and economic growth.

Similarly, the analysis of Lin and Xu (2020) based on provincial data from China also reflected a nonlinear relationship. Adding to this study by Kouton (2019) from the continent of Africa, found that the relationship between energy utilization and economic growth was non-linear. However, most of the studies are still highlighting energy as the main ingredient of economic growth. On the

other side studies also reflected the increase in energy consumption as one of the major threats as it is reversely related to human health (Lin & Zhou, 2022). However, the actual purpose of energy management in the production sector is to foster economic as well as environmental growth cohesively (Meng et al., 2018).

Solar Energy and Energy Efficiency

Therefore, it is optimal to consider solar energy which encompasses various forms of renewable energy resources e.g., solar, wind, hydropower, geothermal, and marine energy, etc. All these forms of energy are potent sources of energy supply that produce no or least hazardous impact on the environment and society as well as on future energy. This form of energy is generated through the conversion of thermal energy into electricity via photovoltaic cells of solar thermal systems. The conversion may yield an unlimited amount of energy that is especially effective for developing countries that do not have access to other forms of competitive energy (Meng et al., 2018). Similarly, mentioned by Renna and Materi (2021) the use of renewable resources in the production sector resulted in a decrease in CO_2 liberation as well as an increase in energy efficiency. However, attaining energy efficiency it is not possible to ignore the importance of the Internet of Things that may substantiate energy efficiency in production firms (May & Kiritsis, 2017).

Energy Efficiency and Sustainable Economic Growth

Energy efficiency is much more important than energy saving but minimal research work is available at the junction of both of these broader concepts termed sustainable manufacturing and smart manufacturing respectively (Meng et al., 2018). Although for the manufacturing sector energy management is significantly important (Gahm et al., 2016) that leads to energy efficiency. Also became the best and most efficient way to protect the environment and also assists firms' financial and non-financial objectives (Fernando & Hor, 2017). In fact, recent studies also confirm the positive association between energy efficiency and sustainable economic growth. In line with SDGs and the vision of 2030, it is almost necessary to relay most upon renewable energy resources in order to produce a positive impact on environment as well as to decrease cost for individuals, households, and businesses (Zakari et al., 2022).

Internet of Things (IoT), Energy Efficiency & Sustainable Economic Growth

Katyarmal et al. (2018), indicated that the role of IoT is exemplary in relating the energy achieved through solar panels to economic growth and betterment. In fact, through advanced algorithms and the use of IT infrastructure monitoring and use of energy might be improved. De Villiers et al. (2021) also indicated the need of IoT in factories to use energy from solar panels effectively and efficiently that may lead to sustainable economic growth

HYPOTHESES

H1: There is a relationship between energy management through solar panels in the production sector and energy efficiency.

H2: There is a relationship between energy efficiency and sustainable economic growth of the country

H3: Energy efficiency mediates the relationship between energy management through solar panels in the production sector and sustainable economic growth of the country

H4: IoT moderates the relationship between energy efficiency and sustainable economic growth of the country

RESEARCH METHODOLOGY

Research Methodology is not only used to make readers understand the technique(s) that are used in any study but also assist researchers in attaining planned objectives and goals associated with the study (Tellis, 1997). Research Methodology may have two major breakdowns i.e., research design and sampling design as indicated by Sekaran and Bougie (2016).

Research Design

For this study, researchers adopted a closed-ended questionnaire to relate the use of solar energy panels in production factories with the economic growth of the country. Previously some of the studies like Cantore et al. (2016) were based upon secondary data collected from surveys of the World Bank for 29 developing countries including Pakistan and India from 2002 to 2004. On the other side, studies are also highlighting the causal relationship between energy consumption and declining social and human health. However, in recent times some countries have taken measures to upset the relationship between economic growth and well-being of their citizens (Fernando & Hor, 2017).

Thus, the optimal choice is to collect data from personnel of the energy sector to gain information associated with the use of solar panels in the production sector on energy efficiency and its reflection upon the economic growth of the country. Therefore, the purpose of the research is correlational (Sekaran & Bougie, 2016) as it relates energy management via the mediating role of energy efficiency on the economic growth of the country. The philosophy of research is epistemology as it is conducted to build knowledge (Saunders et al., 2007). The philosophical stance used to relate research philosophy with research approaches and methodological choices (Saunders et al., 2015) is post-positivism. That is associated with quantitative as well as qualitative research work (Manjikian, 2013). However, mostly this stance applies to quantitative studies (Žukauskas et al., 2018).

Research Sample

Muzammil et al. (2022) posited that Karachi is the largest city and contributes 25% of the GDP of Pakistan. Thus serving 2.5 million consumers in Karachi is much more challenging for K-Electric and therefore relying on renewable energy resources is the need of time. Especially relying on solar and wind energy is much more effective as Karachi is situated in an area where it has ample sunlight as well as wind energy. Thus, collecting data from personnel of the energy sector is legitimate, and previous work e.g., Irfan et al. (2019), has also done the same to portray the significance of solar energy over diversified stakeholders.

Therefore, by capitalizing on non-probability sampling like Abdullah et al. (2017) and using the method of quota sampling like Irfan et al. (2019), this study collects primary data from the energy industry. Hence, the data has been collected based on perceptions from reputed employees of K-Electric ranging from middle to higher management. The total sample size for the study is 100 as the study is based upon the reflection of energy efficiency in the industrial sector on the economic development of Pakistan. The sample size is adequate to be used for SEM-based analysis through SMART-PLS as indicated by (Singkheeprapha et al., 2022). The sample size was also been justified by previous studies like Keith (2019) where the analysis through multiple regression was made on the sample of 100 students. However, initially, 150 questionnaires were circulated but the received number of questionnaires was only 122. Out of 122 questionnaires, 22 were not filled adequately. Hence, the response rate for this study is 75%.

Research Instrument

Research Instrument that is used in this study is a closed-ended adopted questionnaire that is a hybrid of several studies (Chien, 2022; Fernando & Hor,

2017; Lawrence et al., 2019; Purwania et al., 2020; Sola & Mota, 2020; Zhang et al., 2015)

Statistical Technique and Software

Chien (2022), is one of the latest studies that use SMART-PLS to implement structural equation modeling to assess the mediation role of energy efficiency. The study also relates the mediation analysis with economic benefits. Similar has the purpose of this study and therefore the use of the software as well as statistical technique is justified.

STATISTICAL TESTING

It is better to use SEM as compared to regressions (Günzler, 2013) and the implementation of SEM became more efficient with the use of SMART-PLS (Andreev et al., 2009). SEM through SMART-PLS is based upon two models i.e., the inner model and the outer model. The inner model is used to highlight the relationship between variables of interest. However, the outer model is used to indicate the relationship between indicators and latent variables (Wong, 2013). These models have the purpose to shed light on inferential and descriptive statistical analysis that may substantiate the to provide a more rigorous view of statistical analysis (Ogwiji & Lasisi, 2022) by highlighting all the related paths and interrelated effects (Vijayabanu & Arunkumar, 2018). Hence, implementation of SEM through SMART-PLS resulted in the formulation of two different models namely the outer model and inner model. The outer model is used to reflect the relationship between elements and latent variables while the inner model is used to indicate the relationship between major research variables (Wong, 2013).

Figure 2 shows outer loading for each of the elements associated with any of the variables used in the process of research. The loading is the same as of factor loading and it is used to authenticate the inclusion of any indicator (Afthanorhan, 2013). The preferred range of outer loading started from 0.70 although the researcher may include elements with outer loading between 0.60 and 0.70 perhaps the inclusion of these elements may not disturb overall convergent criteria (Sander & Teh, 2014). Therefore, considering Figure 2 it is optimum to declare that figure is reflecting outer loading as none indicator has a value lesser than 0.766.

Table 1 reflects determinants of model fitness e.g., construct reliability and convergent validity. Specifically indicating Cronbach's Alpha along with Goldstein rho and composite reliability are used to reflect construct reliability. Similarly, composite reliability and average variance extracted (AVE) are used to highlight

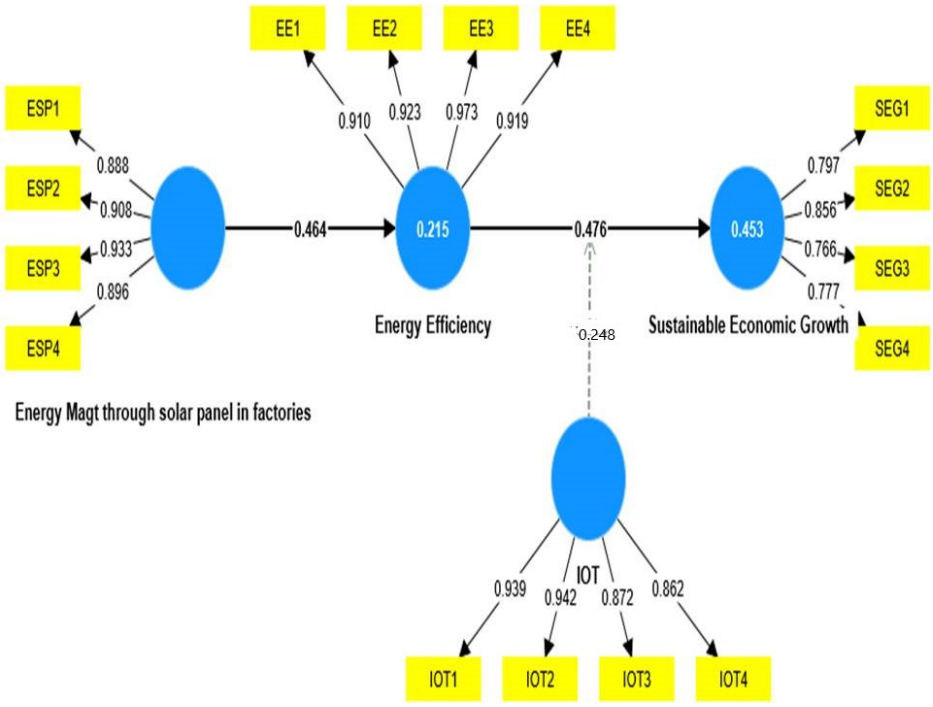

Figure 2: *Path Coefficient (Ringle et al., 2022)*

Table 1.
Construct Reliability and Convergent Validity

	Cronbach alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	AVE
Energy Efficiency	0.949	0.951	0.963	0.868
Energy Management through solar panel in factories	0.928	0.934	0.949	0.822
Internet of Things	0.927	0.960	0.947	0.818
Sustainable Economic Growth	0.813	0.831	0.876	0.639

convergent validity. However, to assure construct reliability as well as convergent validity there is a need to assure some rules and criteria. Specifically, the minimum acceptable value for Cronbach Alpha is 0.40 and for Composite reliability it is 0.60 (Vijayabanu & Arunkumar, 2018). On the other side use of average variance extracted (AVE), alone with value of 0.50 or above is sufficient to reflect convergent validity.

Thus, through considering these criteria the table is not only assuring construct reliability but also convergent validity as the minimum value for Cronbach's Alpha is 0.813 that is much higher than the threshold value and similar is the case for composite reliability and convergent validity where the minimum values in the table are 0.876 and 0.639. Hence, the table is substantially reflecting that the model has construct reliability as well as convergent validity.

Table 2.
Discriminant Validity

	1	2	3	4	5
1. Energy Efficiency	_	_	_	_	_
2. Energy Magt through solar panel in factories	0.491	_	_	_	_
3. IOT	0.531	0.337	_	_	_
4. Sustainable Economic Growth	0.695	0.420	0.577	_	_
5. IOT x Energy Efficiency	0.300	0.187	0.378	0.353	_

Table 2 highlights discriminant validity. However, among three of the major measure used to reflect discriminant validity i.e., Heterotrait-Monotrait ratio (HTMT), Cross-Loading & Fornell and Larker criterion $ this study is using HTMT. HTMT is the most preferred measure to reflect heterotrait-monotrait ratio and to assure the presence of discriminant validity the table must not contain any value higher than 0.85 (Hair & Sarstedt, 2019). Therefore, Table 2 shows discriminant validity in the model as there is no value in the table that is higher than 0.695.

Table 3.
Predictive Accuracy

	R-square	R-square adjusted
Energy Efficiency	0.583	0.561
Sustainable Economic Growth	0.413	0.402

Table 3 indicates the quality criteria through the path coefficient. The tool is also known as the coefficient of determination. In fact, the purpose is to reflect the predictive accuracy of the independent variable which is donated by R-square. In actual predictive accuracy is based upon the reliability of the outer (structural) and inner (measurement) models (Purwanto et al., 2020). There are three different criteria to assess the impact of independent variables over the dependent variables i.e., 0.25, 0.50, and 075 that are perceived as low, moderate, and substantial impacts (Wong, 2013). Thus, in light of the given criteria, the model used in the study is effective in assuring the impact of renewable energy through solar systems in the production sector over energy efficiency as well as

Table 4.
Path Coefficient

	Original sample	Sample mean	Standard deviation (STDEV)	T stats. (|O/STDEV|)	P values
Energy Efficiency -> Sustainable Economic Growth	0.476	0.476	0.062	7.734	0.000
Energy Magt through solar panel in factories -> Energy Efficiency	0.464	0.463	0.075	6.184	0.000
IOT -> Sustainable Economic Growth	0.242	0.248	0.073	3.298	0.001
IOT x Energy Efficiency -> Sustainable Economic Growth	0.198	0.412	0.039	5.076	0.000

on sustainable economic growth of Pakistan. In fact, the values are moderate for mediating (indirect) relations and substantially above the lowest criteria for predictive accuracy for the dependent variable.

In Table 4, path coefficient is used to reflect the relationship of variables that are included in the measurement model of PLS-SEM through SMART-PLS (Silaparasetti et al., 2017). Hence legitimate to declare that the table is a part of the inferential statistical side and it works upon the defined criteria of p-values and t-values. No relationship can be validated if the t-value is not greater than or equal to 1.97 and the p-value is lesser than or equal to 0.05.

Hence, in light of the mentioned criteria, the use of renewable energy from the use of solar panels in the production sector is a significant predictor of energy efficiency. Energy efficiency is also found to be beneficial for sustainable economic growth and moderation of the Internet of Things (IoT) with energy efficiency also found to have a positive impact on sustainable economic growth.

Table 5 reflects specific indirect effects.reflects the mediation analysis for the inferential section of the analysis. However, the table also uses the same criteria of t-values and p-values as used by Table 4 to reflect the relationship(s). Hence, it is effective to reflect those criteria developed by Hair et al. (2017) are not only valid for path coefficient but also for specific indirect effects as indicated by Hair and Sarstedt (2019). Thus, the specific indirect effect of energy management through solar panels in factories is also found to be positively associated with sustainable economic growth. Hence, based on the analysis, all of the postulates,

Table 5.
Specific Indirect Effect

	Original sample	Sample mean	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Energy Magt through solar panel in factories -> Energy Efficiency -> Sustainable Economic Growth	0.221	0.222	0.051	4.318	0.000

relationships, and hypotheses are found to be true. . Moreover, the value for moderation analysis is found to be higher in comparison to the serial mediation analysis which confirms the use of moderation, i.e., (IoT) for relating energy produced by solar panels to sustainable economic growth

CONCLUSION AND DISCUSSION

This study is one of the premier studies from the context of developing countries like Pakistan and statistical testing proves all the relationships and claims formulated through this study. Therefore, it is optimal to discuss initially the model's fitness, reliability, validity, and predictive accuracy. At the beginning of the analysis, the findings of the study are consistent with Dincer (2011) as the use of renewable energy is also recommended for the industrial sector of developing countries like Pakistan. The amount of energy produced from solar energy can cause energy efficiency that is consistent with the indications of Mekhilef et al. (2011).

In fact, by considering the work of Goswami and Kreith (2007); Mekhilef et al. (2011) the use of energy management through solar panels and mediation of energy efficiency has been proven. This also signifies the selection of IoT as the moderator to check and verify the use of IT resources for better energy use. In fact, the higher-value for moderation analysis also indicated the significance of IoT for sustainable economic growth and it is also in line with the indications made by Katyarmal et al. (2018)

Similarly reliability, validity, model fitness, and predictive accuracy of the model also confirm the use of sustainable economic growth as the dependent variable as indicated by Jan et al. (2021). Relating the section of discussion with the inferential section of the study it has been observed that the findings of the study are consistent with Chen et al. (2022) as energy generated with renewable energy resources like solar panels is found to increase energy efficiency. The use of renewable energy resources like solar panels is especially important for

developing countries of the world. Moreover, these resources also can produce an ample amount of energy required for energy efficiency. Hence, the findings are also consistent with Meng et al. (2018); Renna and Materi (2021). Last but not the least findings of the study also reflect that the use of IoT is beneficial for economic development. Thus, found consistent with the indications of Gahm et al. (2016).

POLICY IMPLICATIONS

The findings of this study indicated that the production sector must use solar panels for attaining energy efficiency and to support sustainable economic growth. Hence, government must provide some incentives or provide solar panels at discounted prices to the production sector. Similar was recommended by Shahsavari and Akbari (2018) with special emphasis on developing countries. However, the importance of research and development cannot be undermined and therefore study also recommends research and development must be emphasized to lure with the advantages of renewable resources (Dincer, 2011).

RECOMMENDATIONS AND FUTURE DIRECTION

After detailed statistical testing, it has been recommended that production sector firms must develop proper policies to take advantage of available renewable energy resources. However, in addition to the proper policy formulation, there is also a need to use a proper and well-developed IT network to take full advantage of the resources and attain energy efficiency through effectively utilizing energy. For this purpose, there is a need for continuous research in this vein and therefore there is a need to analyze the impact of solar energy on other sectors as well like telecommunication, media, banking and higher education, etc. Moreover, the use of expanded construct for energy management may also be found fruitful to understand the mediation as well as serial mediation impact of related variables over sustainable economic growth.

CONFLICT OF INTEREST

The authors unequivocally affirm that there are no existing financial or personal conflicts of interest that could influence the outcome of this study. Additionally, no financial assistance or remuneration has been received for the execution of this research or the composition of this article. We also confirm that we have no direct financial or personal affiliations that could potentially bias the results or interpretations presented herein.

REFERENCES

Abbas, A., Waseem, M., & Yang, M. (2020). An ensemble approach for assessment of energy efficiency of agriculture system in Pakistan|. *Energy Efficiency*, *13*, 683–696. https://doi.org/10.1007/s12053-020-09845-9

Abdullah, Z. D., Shah, T., Jebran, K., Ali, S., Ali, A., & Ali, A. (2017). Acceptance and willingness to pay for solar home system: survey evidence from northern area of Pakistan. *Energy Rep*, *3*, 54–60. https://doi.org/10.1016/j.egyr.2017.03.002

Adnan, S., Khan, A. H., Haider, S., & Mahmood, R. (2012). Solar energy potential in Pakistan. *Journal of renewable and Sustainable Energy*, *4*(3). https://doi.org/10.1063/1.4712051

Afthanorhan, W. M. A. B. W. (2013). A comparison of partial least square structural equation modeling (PLS-SEM) and covariance based structural equation modeling (CB-SEM) for confirmatory factor analysis. *International Journal of Engineering Science and Innovative Technology*, *2*(5), 198–205.

Andreev, P., Heart, T., Maoz, H., & Pliskin, N. (2009). Validating formative partial least squares (PLS) models: methodological review and empirical illustration. *ICIS Proceedings, 193*. Retrieved from https://aisel.aisnet.org/icis2009/193

Aqeel, A., & Butt, M. S. (2001). The relationship between energy consumption and economic growth in Pakistan. *Asia-Pacific Development Journal*, *8*(2), 101–110.

Cagno, E., Moschetta, D., & Trianni, A. (2019). Only non-energy benefits from the adoption of energy efficiency measures? A novel framework. *Journal of cleaner production*, *212*, 1319–1333. https://doi.org/10.1016/j.jclepro.2018.12.049

Cantore, N., Calì, M., & Velde, D. W. (2016). Does energy efficiency improve technological change and economic growth in developing countries. *Energy Policy*, *92*, 279–285. https://doi.org/10.1016/j.enpol.2016.01.040

Chen, H., Shi, Y., & Zhao, X. (2022). Investment in renewable energy resources, sustainable financial inclusion and energy efficiency: A case of US economy. *Resources Policy*, *77*, 102680. https://doi.org/10.1016/j.resourpol.2022.102680

Chien, F. (2022). The mediating role of energy efficiency on the relationship between sharing economy benefits and sustainable development goals (Case Of China). *Journal of Innovation & Knowledge*, *7*(4), 100270. https://doi.org/10.1016/j.jik.2022.100270

De Villiers, C., Kuruppu, S., & Dissanayake, D. (2021). A (new) role for business-Promoting the United Nations' Sustainable Development Goals through the internet-of-things and blockchain technology. *Journal of business research*, *131*, 598–609. https://doi.org/10.1016/j.jbusres.2020.11.066

Dincer, F. (2011). The analysis on photovoltaic electricity generation status, potential and policies of the leading countries in solar energy. *Renewable and sustainable energy reviews*, *15*(1), 713–720. https://doi.org/10.1016/j.rser.2010.09.026

Dołęga, W. (2019). Selected aspects of national economy energy efficiency. *Polityka Energetyczna-Energy Policy Journal*, 19–32. https://doi.org/10.33223/epj/111987

Fernando, Y., & Hor, W. L. (2017). Impacts of energy management practices on energy

efficiency and carbon emissions reduction: a survey of Malaysian manufacturing firms. Resources. *Conservation and Recycling*, *126*, 62–73. https://doi.org/10.1016/j.resconrec.2017.07.023

Gahm, C., Denz, F., Dirr, M., & Tuma, A. (2016). Energy-efficient scheduling in manufacturing companies: A review and research framework. *European Journal of Operational Research*, *248*(3), 744–75. https://doi.org/10.1016/j.ejor.2015.07.017

Goswami, D. Y., & Kreith, F. (2007). *Handbook of energy efficiency and renewable energy* (1st ed.). Crc Press. https://doi.org/10.1201/9781420003482

Günzler, H. (2013). Definitions of almost periodicity. *arXiv preprint arXiv:1303.2337*, 2337.

Hair, J. F., Hult, G. T. M., Ringle, C. M., Sarstedt, M., & Thiele, K. O. (2017). Mirror, mirror on the wall: a comparative evaluation of composite-based structural equation modeling methods. *Journal of the academy of marketing science*, *45*(5), 616–632. https://doi.org/10.1007/s11747-017-0517-x

Hair, J. F., & Sarstedt, M. (2019). Factors versus composites: Guidelines for choosing the right structural equation modeling method. *Project Management Journal*, *50*(6), 619–624. https://doi.org/10.1177/8756972819882132

Irfan, M., Zhao, Z. Y., Ahmad, M., & Mukeshimana, M. C. (2019). Solar energy development in Pakistan: Barriers and policy recommendations. *Sustainability*, *11*(4), 1206. https://doi.org/10.3390/su11041206

Jan, I., Durrani, S. F., & Khan, H. (2021). Does renewable energy efficiently spur economic growth? Evidence from Pakistan. Environment. *Development and Sustainability*, *23*, 373–387. https://doi.org/10.1007/s10668-019-00584-1

Katyarmal, M., Walkunde, S., Sakhare, A., & Rawandale, U. S. (2018). Solar power monitoring system using IoT. *Int Res J Eng Technol (IRJET)*, *5*(3), 2395–0056.

Keith, T. Z. (2019). Multiple regression and beyond: An introduction to multiple regression and structural equation modeling. *Routledge*. https://doi.org/10.4324/9781315162348

Kouton, J. (2019). The asymmetric linkage between energy use and economic growth in selected African countries: Evidence from a nonlinear panel autoregressive distributed lag model. *Energy Economics*, *83*, 475–490. https://doi.org/10.1016/j.eneco.2019.08.006

Lawrence, A., Nehler, T., Andersson, E., Karlsson, M., & Thollander, P. (2019). Drivers, barriers and success factors for energy management in the Swedish pulp and paper industry. *Journal of cleaner production*, *223*, 67–82. https://doi.org/10.1016/j.jclepro.2019.03.143

Lee, C. C., & Chang, C. P. (2007). Energy consumption and GDP revisited: a panel analysis of developed and developing countries. *Energy economics*, *29*(6), 1206–1223. https://doi.org/10.1016/j.eneco.2007.01.001

Lin, B., & Xu, B. (2020). How does fossil energy abundance affect China's economic growth and CO2 emissions? *Science of the Total Environment*, *719*, 137503. https://doi.org/10.1016/j.scitotenv.2020.137503

Lin, B., & Zhou, Y. (2022). Does energy efficiency make sense in China? Based on

the perspective of economic growth quality. *Science of the Total Environment*, *804*, 149895. https://doi.org/10.1016/j.scitotenv.2021.149895

Manjikian, M. (2013). Positivism, post-positivism, and intelligence analysis. *International Journal of Intelligence and CounterIntelligence*, *26*(3), 563–582. https://doi.org/10.1080/08850607.2013.758002

May, G., & Kiritsis, D. (2017). Business model for energy efficiency in manufacturing. *Procedia Cirp*, *61*, 410–415. https://doi.org/10.1016/j.rser.2010.12.018

Mekhilef, S., Saidur, R., & Safari, A. (2011). A review on solar energy use in industries. *Renewable and sustainable energy reviews*, *15*(4), 1777–1790. https://doi.org/10.1016/j.rser.2010.12.018

Meng, Y., Yang, Y., Chung, H., Lee, P. H., & Shao, C. (2018). Enhancing sustainability and energy efficiency in smart factories: A review. *Sustainability*, *10*(12), 4779. https://doi.org/10.3390/su10124779

Muzammil, S., Akhund, S. A., & Channa, F. (2022). An Empirical Study on Solar Performance, Cost, and Environmental Benefits of Solar Power Supply. *International Journal of Circular Economy and Waste Management (IJCEWM)*, *2*(1), 1–23. https://doi.org/10.4018/IJCEWM.302203

Ogwiji, J., & Lasisi, I. O. (2022). Internal control system and fraud prevention of quoted financial services firms in Nigeria: A Smart PLS-SEM approach. *European Journal of Accounting, Auditing and Finance Research*, *10*(4), 1–13. https://doi.org/10.37745/ejaafr.2013/vol10no4pp.1-13

Purwania, I. B. G., Kumara, I. N. S., & Sudarma, M. (2020). Application of IoT-Based System for Monitoring Energy Consumption. *International Journal of Engineering and Emerging Technology*, *5*(2), 81–93.

Purwanto, A., Asbari, M., Santoso, T. I., Paramarta, V., & Sunarsi, D. (2020). Social and management research quantitative analysis for medium sample: comparing of Lisrel, Tetrad, GSCA, Amos, SmartPLS, WarpPLS, and SPSS. *Jurnal Ilmiah Ilmu Administrasi Publik: Jurnal Pemikiran Dan Penelitian Administrasi Publik*, *9*(2), 518–532. https://doi.org/10.31538/ndh.v6i2.1575

Renna, P., & Materi, S. (2021). A literature review of energy efficiency and sustainability in manufacturing systems. *Applied Sciences*, *11*(16), 7366. https://doi.org/10.3390/app11167366

Ringle, C. M., Wende, S., & Becker, J. M. (2022). SmartPLS 4. Oststeinbek: SmartPLS GmbH. *J. Appl. Struct. Equ. Model*.

Sander, T., & Teh, P. L. (2014). SmartPLS for the human resources field to evaluate a model. In *proceedings of New Challenges of Economic and Business Development.* University of Latvia.

Saunders, M. N., Lewis, P., Thornhill, A., & Bristow, A. (2015). *Understanding research philosophy and approaches to theory development.*

Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach.* john wiley & sons.

Shaari, M., Hussain, N., & Ismail, M. (2013). Relationship between energy consumption and economic growth: Empirical evidence for Malaysia. *Business Systems Review*, *2*(1), 17–28.

Shahsavari, A., & Akbari, M. (2018). Potential of solar energy in developing countries for reducing energy-related emissions. *Renewable and Sustainable Energy Reviews*, *90*, 275–291. https://doi.org/10.1016/j.rser.2018.03.065

Silaparasetti, V., Rao, G. V. R., & Khan, F. R. (2017). Structural equation modeling analysis using smart pls to assess the occupational health and safety (OHS) factors on workers' behavior. *Humanities & Social Science Reviews*, 2395–7654. eISSN, 2395-7654.

Singkheeprapha, P., Jumani, Z. A., & Sukhabot, S. (2022). Is Islamic Brand attitudes influence Thai Muslims' buying behavioural intentions: a quantitative analysis using smart-PLS. *Journal of Islamic Marketing*, *13*(11), 2403–2420. https://doi.org/10.1108/JIMA-08-2020-0252

Sola, A. V., & Mota, C. M. (2020). Influencing factors on energy management in industries. *Journal of Cleaner Production*, *248*, 119263. https://doi.org/10.1016/j.jclepro.2019.119263

Tellis, W. (1997). Application of a case study methodology. *The qualitative report*, *3*(3), 1–19. https://doi.org/10.46743/2160-3715/1997.2015

Vijayabanu, C., & Arunkumar, S. (2018). Strengthening the team performance through personality and emotional intelligence: Smart PLS approach. *Scientific Annals of Economics and Business*, *65*(3), 303–316. https://doi.org/10.2478/saeb-2018-0019

Žukauskas, P., Vveinhardt, J., & Andriukaitienė, R. (2018). Philosophy and paradigm of scientific research. *Management culture and corporate social responsibility*, *121*, 139. https://doi.org/10.5772/intechopen.70628

Wong, K. K. K. (2013). Partial least squares structural equation modeling (PLS-SEM) techniques using. *SmartPLS. Marketing Bulletin*, *24*(1), 1–32.

Zakari, A., Khan, I., Tan, D., Alvarado, R., & Dagar, V. (2022). Energy efficiency and sustainable development goals (SDGs). *Energy*, *239*, 122365. https://doi.org/10.1016/j.energy.2021.122365

Zhang, B., Wang, Z., & Lai, K. H. (2015). Mediating effect of managers' environmental concern: Bridge between external pressures and firms' practices of energy conservation in China. *Journal of Environmental Psychology*, *43*, 203–215. https://doi.org/10.1016/j.jenvp.2015.07.002