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Sustainable Economic Growth: Mediation Effect of Decrease of Energy Crises through the Use of Solar PVs

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Abstract

Sustainability is one of the prime issues across the world. Therefore, it is also included in the list of Sustainable Development Goals (SDGs). Therefore, the implications are much higher for developing sides of the world. Therefore, this study has been conducted specifically to check the use of on-roof installation of solar PVs in urban residential areas on the decrease of energy shortfall as well as upon sustainable growth of the country's economy. Although for the purpose of data collection, the sample has been drawn from the energy sector companies of Karachi in order to reflect vividly upon the sustainable economic growth of the country. The sample size is of 125 respondents based on employees of energy sector. Analysis has been made through SMART-PLS using PLS-SEM findings indicating that the use of on-roof solar PVs is substantial for the decrease in energy shortfall as well as for the sustainable economic growth of the country. In fact, the outcomes of the study also prove the use of mediation through indicating indirect association between use of solar PVs at country's economic growth.

Keywords: Solar PVs, Energy Crises, Sustainability, Economic Growth.

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1. INTRODUCTION

Continuous rise in technology is making the world transform in to digital era. However, in this era, the demand for electricity has also increased significantly as electricity is not only the main source of energy for individual and household requirements but also a diverse set of industries. Hence the demand for energy has increased significantly and power generating plants are getting de-regularized which causes a significant surge in the cost of per unit electricity consumption (Mahapatra & Nayyar, 2019). However, most of the studies associated with energy system highlighted individuals as well as households as the consumer.

However, these consumers may also be transformed into producers. This statement becomes true due to the revolution of renewable energy sources and during the wake of this era, individuals and households transformed into energy producers. Therefore, it is better to use the word "*Prosumers*" & the way of energy utilization has been addressed by several researchers (Wittenberg & Matthies, 2016). Therefore, since 2016 there is a significant surge in the use of renewable resources. In fact, most of the Western and developed countries are adopting renewable energy resources in order to combat issues associated with energy security. However, in Asian countries like China adoption of renewable resources is grounded on environmental issues & to electrify rural and under-developed areas of the country. Studies mentioned solar energy as the major source of renewable energy production across the globe (Alsabbagh, 2019).

The use of solar panels is one of the best alternative sources for fossil fuels and also has the tendency to provide sustainable energy to fulfill needs in an adequate way. In fact, solar energy is also non-toxic as it does not liberate CO_2, SO_2 & No_x, and therefore the preference for solar energy has significantly increased around the globe. Moreover, studies also reflected that solar panels have the tendency to fulfill present as well as future consumption of energy as the world approximately receives 1, 73,000 TW of solar energy in comparison to the requirement of 15 TW (Shahsavari et al., 2018).

Pakistan is the country where the major consumers of electricity are households and consume around 45.10% of total electricity. However, the oil and gas resources of the country are not capable of fulfilling the surge in the requirement of electricity. Hence increase of load shedding causes a severe increase in the use of oil-based generators which causes an increase in environmental and climatic harms (Raza *et al.,* 2020). On the other side world is also evidencing a continuous increase in the photovoltaic (PV) systems connected to the electric grid for transferring energy to the grid (Wittenberg & Matthies, 2016).On the other side electric gird may have several PV systems that may harm the grid and reduce their efficiency in the long run. Therefore, countries are also providing incentives for the installation of battery storage systems. Batteries make consumers use electricity generated from renewable resources during the daytime for usage in later parts of the day (Wittenberg & Matthies, 2016).

Pakistan is also ranked high in the list of countries that have massive potential for renewable energy resources like hydro-power and solar energy etc. Thus, realizing the potential of renewable energy resources in Pakistan the government is trying to redefine the energy mix elements through incorporation of renewable energy resources (Jan et al., 2021). In fact, it is necessary as around 60% of the country's population is still using biomass as of a severe shortage of gas and electricity. On the other side industrial sector also suffering from a severe shortage of power and the major reasons for suffering are power theft, lower recovery, line losses, and expensive furnace oil (Uram et al., 2021). Hence the purpose of this study is to explore the significance and scope of PV-based power generation on the energy shortfall and

sustainable economic growth. Thus the significance of this study has many folds as it does not only indicate the importance of personal solar system but also highlight the importance of solar energy for personal use. In fact, an increase in personal solar panels will make energy supply from the grid focus more on rural and industrial areas. Therefore, following research questions could be formed:

RQ1: What is the significance of solar PVs in Pakistan?

RQ2: How use of solar PVs affect economic growth?

RQ3: What are the benefits of a decrease in energy shortfall to the economy of Pakistan?

Reduction in the cost of electricity and attaining equilibrium in electricity demand and supply are the prime areas of research in the past few decades. Thus, research provides different explanations and methods for managing electricity demand as well as managing peak-to-average load (Aslam et al., 2018). Hence, there is a need to consider other renewable resources other than hydro-power for the development of better policies associated with the use of renewable energy resources that may foster economic growth of Pakistan (Jan et al., 2021). However, the new way to address demand side management for electricity has been addressed by a few of the studies e.g., Bahaj and James (2007); Dobbyn and Thomas (2005); Haas et al (1999), and Keirstead et al (2012).

On the other side, a lack of knowledge at the consumer level hinders the use of personal solar energy panels. Similar points were posited by Alsabbagh (2019) highlighted that consumers in Bahrain have very little knowledge about the benefits of solar home systems. Similar was the results from Australia where residents were unaware of the environmental benefits of using solar home systems. However, a survey from the inhabitants of Pakistan highlighted that people are interested in purchasing and installation of solar home systems if the government may provide subsidies for purchase. In fact, a 50% subsidy from the government may increase the use of solar home systems substantially as the survey reflected that 77% of the respondents are willing to use solar home systems if available at mentioned subsidized rates (Abdullah et al., 2017).

However, still there is a lack of studies that may address the use of renewable resources in Pakistan but effective utilization of renewable energy resources may play a significant role in dealing with energy shortfalls (Rafique & Rehman, 2017).

2. LITERATURE REVIEW

Pakistan is continuously facing a shortfall in energy as the difference between supply and demand is mounting on a continuous basis. The major reason behind the shortfall is the increase of population as well as relying only upon prime energy resources Hence deficiency of electricity became a common phenomenon which is also reflecting negatively upon the economic growth of the country. On the other side increase of urbanization is also causing a substantial increase in electricity consumption and it has been estimated that by 2050 the demand for energy will increase thrice. However, there is no considerable increase in the level of supply.

Therefore there is a need to take creative measures and also to use non-traditional sources for the production of energy. Thus, there is a need to capitalize on natural resources like solar, wind, thermal, etc to overcome the crisis of energy. In fact, these resources are also environmentally friendly and do not liberate any of the greenhouse gases. Therefore, these resources are used all over the globe for the production of renewable energy, and in Pakistan solar and wind can also be used as reliable sources to produce renewable energy. In fact, the potential of renewable energy resources is around 167.7 GW which is around 8 times the current energy demand i.e., 21 GW (Rafique & Rehman, 2017). Therefore, there is a substantial need to increase production of renewable energy especially in urban and rural areas of Sindh and Punjab provinces. This can also be done through capitalizing on the massive potential of solar energy as on average Pakistan receives sunshine around 3300h/year (Raza et al., 2020).

Studies were conducted to understand the scope of solar energy for residential areas to understand the existence and impact of net zero energy building. The analysis reflected that solar photovoltaics can fulfill almost full electricity demand for the entire year. The use of solar energy is also determined to be convenient as well as economical as the solar energy systems also have low payback period of as low as less than seven years (Hoseinzadeh et al., 2020). The use of solar energy not only provides constant but abundant & clean energy available to human beings. The source also can provide energy that can fulfill the growing demand for energy by human beings. The period of gestation for solar energy is also substantially low and therefore it is also less costly as compared to the other forms of renewable energy. Therefore, it is less expensive and transmission costs & losses can further be mitigated by using technological devices. On the other side installation cost of solar panels as well as solar cells has also fallen apart which caused a substantial increase in the installation of solar panels (Rahut et al., 2016). Pv-based may also enhance self-consumption by affecting the share of electricity the household receives from gird. Therefore, it is legitimate to declare that Pv-based systems also have the potential to diminish the overall consumption of electricity (Wittenberg & Matthies, 2016).

Moreover, household solar panels are also perceived as one of the major factors in dealing with environmental, economic, and climatic changes. Moreover, the use of solar energy is also one of the major predictors of the low-carbon economy that is based upon the increase in economic development & decline in CO_2 emission (Iram et al., 2021). Similar was the case of India when Prime Minister Manmohan Singh realized the importance of solar energy for the economic growth of the country (Srivastava & Srivastava, 2013). Moreover, solar energy is non-hazardous and better to be used for economic and environmental betterment. In fact, it is also free from noise pollution, and under the current declining economy it is the best source of energy that is not only cost-efficient but also sheds pressure to import expensive fossil fuels from the government (Irfan et al., 2019).

Studies also indicate that rooftop installation of solar PVs can provide 75% of the total energy requirements. Although there are

some challenges to the proper location for installation of solar PV like the approach to calculating the size of PV investment, the interaction between self-consumption, access units produced, and policy of reimbursement for additional units & specific government schemes for primary stakeholders. However the decline in the prices of batteries will enhance the desirability of solar PVs (Alqahtani & Balta-Ozkan, 2021).

Studies also indicated that urban areas always require more electricity than rural areas. Inhabitants of urban areas also use machinery that requires high power, and therefore electricity failure is also common. On the other side increase in urbanization is also causing demand for power by personal as well as organizational consumers. Therefore inhabitants of urban areas are also considering using other sources of energy supply especially renewable energy sources like solar panels. The decision is also being proven due to continuous increase in the prices of fossil fuels and decrease in the prices of batteries which are one of the major components of PV-based solar system (Gautam et al., 2015).

Moreover, the availability of ample sunlight throughout the day will cause an increase in units produced thus will also making the use of batteries more applicable in urban areas (Alqahtani & Balta-Ozkan 2021). Therefore, legitimate to quote Shahsavari et al (2018) that solar energy is the way to attain effectiveness at low as well as high scales in an affordable, practical, sustainable, and environmentally safe manner. Using solar PVs to obtain electricity is more relevant and applicable to developing sides of the world. However, lack of research work associated with the adaptation of solar PVs by residents, and thus gap also prevails about the motivation to install solar PV on roofs. Although the review of the literature highlighted that in addition to subjective norms, novelty, and intention the environmental concern of residents cannot be discarded from the list of factors deemed important for the installation of solar PVs (Fauzi et al., 2023)

2.1 RESEARCH HYPOTHESES

H_1A: There is a relationship between household solar panels and a decrease in energy crises

H_2A: There is a relationship between the decrease in energy crises and the sustainable economic growth of Pakistan

H_3A: Decrease in energy crises mediates between the use of household solar panels and sustainable economic growth of Pakistan

3. RESEARCH METHODOLOGY

Research Methodology is the art by which researchers not only discuss research methods but also the logic that makes researchers prefer specific methods to conduct research. Research methodology is a broad concept that also includes research methods (Kothari, 2004) as well as sampling methods (Sekaran & Bougie, 2016) for making research work authentic and effective. Hence the research methodology of this study is also bifurcated into research design and sampling design.

3.1 Research Design:

Very few studies are focused on the electricity consumption & energy-saving behavior of households. However, among these most of

the studies were conducted in the United Kingdom with significant variation in methodological approaches and small sample sizes (Wittenberg & Matthies, 2016). Therefore this study has been done about the installation of on-roof solar PVs in Karachi which is a mega city in Pakistan (Qureshi et al., 2013). Karachi also has immense potential for installing on-roof solar PVs (Khan & Arsalan, 2016) and is therefore suited best for the impact of energy management through on-roof solar panels. However, there was almost no study that tried to understand the impact previously. Therefore, the philosophy of research used in the study is epistemology which is perceived as the philosophy of knowledge as indicated by Bernecker and Pritchard (2011).

The philosophical stance associated with this study is post-positivism which is mostly found to be associated with quantitative research work (Žukauskas et al., 2018). The purpose of the study is correlational (Sekaran & Bougie, 2016) as it used a complex model for analyzing the effect of energy management through the installation of on-roof solar PVs over economic growth. A similar was highlighted by Pirlott and MacKinnon (2016) about the mediation effect and correlational study design. The research approach was deductive, the research strategy was surveyed, the methodological choice was mono-method and the time horizon was cross-sectional (Saunders et al., 2015)

3.2 Sampling Design:

Study Abdullah et al. (2017) conducted their study from the northern sides of Pakistan to contribute positively towards the significance of home-based solar systems. The sample size of the study was 350 respondents and was only limited to Malakand. However, to contribute effectively to the significance of solar systems used at home studies like Irfan et al. (2019) collect primary data from an energy industry professional to reflect the impact of renewable energy in a more vivid manner. The study also mentioned that Karachi is the largest city in Pakistan and contributes 25% to the country's GDP. Therefore, this study collects data from energy officials from Karachi to highlight the significance of solar home systems in a more appropriate manner. The postulate is appropriate as K-Electric supplies electricity to more than 2.5 million customers and relying on home-based solar panels is not only beneficial for consumers but also for the overall economy (Muzammil et al., 2022). The sample size for the study is 125 and the response rate is around 71% as initially 175 questionnaires were circulated.

3.3 Research Instrument:

The research instrument used for this study was a structured closed-ended questionnaire that was adapted from multiple studies to increase rigor as well as reliability of the findings. Major studies that contributed to the development of this research instrument are Chien (2022); Fernando and Hor (2017); Lawrence et al. (2019); Parsad et al. (2020) and Purwania et al. (2020). Appendix A shows the questionnaire used for data collection.

4. RESULTS

Structural Equation Modeling preferably known as SEM is the second generation multi-variant data analysis tool that is perceived as

more thorough and rigorous in producing statistical analysis in comparison to the regression (Gunzler *et al.,* 2013). Implementation of SEM becomes more effective when it is implemented through using SMART-PLS (Wong, 2013). The breakdown of analysis in descriptive and inferential portion provide a better analysis (Khoshmaram et al., 2017 & Ogwiji & Lasisi, 2022) while SMART-PS reflects all the necessary relations and paths in the research model (Vijayabanu & Arunkumar, 2018). The purpose of the outer model of SEM is to highlight the relation between elements and latent variables while the inner model is used to highlight the association between major research variables.

Figure 1: *Outer Loading (CFA)*

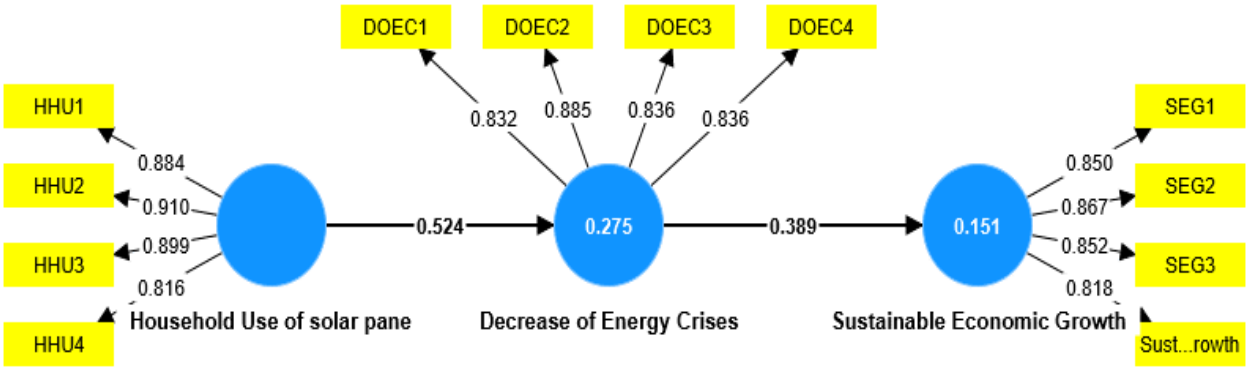

Figure 1 is used to make readers observe the outer loading for each of the elements used in the research. The use of outer loading is similar to the factor loading (Afthanorhan, 2013) and the range of acceptable values starts from 0.70. However, if the convergent validity does not get disturbed then the researcher is allowed to include elements with outer loading between 0.60 & 0.70 (Sander & Teh, 2014). Although considering the outer loading values from Figure 1 it has been observed that no value is lower than 0.816. Thus, the confirmatory factor analysis has been conducted successfully and
the elements included research process.

Table 1: Construct Reliability & Convergent Validity

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Decrease of Energy Crises	0.869	0.870	0.910	0.718
Household Use of solar pane	0.901	0.905	0.931	0.771
Sustainable Economic Growth	0.869	0.869	0.910	0.717

Table 1 is positioned to make users view the authenticity of all the variables that are used in research through construct reliability and convergent validity. The indicators of construct

reliability and convergent validity are further bifurcated in order to provide ease to readers. Cronbach's Alpha, Goldstein rho, and composite reliability while composite reliability and average variance extracted (AVE) are used to reflect convergent validity. The threshold values for Cronbach's Alpha and Goldstein rho are 0.40 and 0.60 respectively (Vijayabanu & Arunkumar, 2018) but when the researcher is using AVE to reflect convergent validity then the value must be equal to or greater than 0.50. However, according to Table 2, the minimum values for Cronbach's Alpha and Goldstein rho are 0.869; 0.910 for convergent validity & 0.717 for AVE. All of these values are much lesser than the benchmark values and therefore confirming the presence of construct reliability & convergent validity in this study.

Table 2: Discriminant Validity

	Decrease of Energy Crises	Household Use of solar pane	Sustainable Economic Growth
Decrease of Energy Crises			
Household Use of solar pane	0.591		
Sustainable Economic Growth	0.446	0.401	

Table 2 has been plotted vividly to indicate discriminant validity through the most preferred tool of discriminant validity, i.e., the Heterotrait-Monotrit ratio (Iqbal et al., 2021). The maximum value that may assure discriminant validity is 0.85 and any higher value is unacceptable in this regard (Hair *et al.,* 2021). Hence, in line with the benchmark values for the Hetertrait-Monotrait ratio, the table assures the presence of discriminant validity as no value in Table 2 is equal to or greater than 0.85.

Table 3: Predictive Accuracy

	R-square	R-square adjusted
Decrease of Energy Crises	0.475	0.472
Sustainable Economic Growth	0.351	0.348

Table 3 has the goal to reflect predictive accuracy which is technically known as the coefficient of determination that is used to evaluate the authenticity of the structural and measurement model of SEM used through SMART-PLS (Purwanto et al., 2020). Although there are three benchmarks of the impact that may be caused by the change in 1% of the value of the independent variable, i.e., low, moderate, and substantial that are based on 0.25, 0.50 & 0.75 or above values (Wong, 2013). Hence in light of the benchmark values, it is appropriate to declare that the table sufficiently addresses

predictive accuracy for direct as well as indirect effects.

Table 4: Path Coefficient

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Decrease of Energy Crises -> Sustainable Economic Growth	0.389	0.392	0.086	4.541	0.000
Household Use of solar panel -> Decrease of Energy Crises	0.524	0.522	0.079	6.671	0.000

Table 4 is used to highlight the path coefficient which is the way to analyze the impact of variables on each other. The table is a part of the inferential statistical part along with the predictive accuracy and in-direct effects. The purpose of the path coefficient is to highlight the relationship of variables in the measurement (inner) model (Silaparaasetti et al., 2017) based on values that appeared for t-statics and p-values. However, the relationship is acceptable if the value of t-statistics is equal to or greater than 1.97 along with the p-value that needs to be lesser than or equal to 0.05 (Hair *et al*., 2017).

Hence in the light of these criteria, it has been deduced that there is a definite relationship between Household use of solar panels & decrease in energy crises and a decrease in energy crises & sustainable economic growth.

Table 5: Specific Indirect Effect

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Household Use of solar panel -> Decrease of Energy Crises -> Sustainable Economic Growth	0.204	0.207	0.062	3.279	0.001

Table 5 is used to indicate specific indirect effects as the part of inferential analysis for the inner model of structural equation modeling conducted by SMART-PLS. The criteria for validating the impact is the same as that of Table 4, i.e., based upon t-values and p-values as indicated by Hair et al (2017) and Hair et al (2021). Thus in the light of benchmarked values, it has been deduced that there is a definite presence of an indirect association between household use of solar panels and sustainable economic growth (summary of hypotheses presented in Table 6).

Table 6: Hypotheses Acceptance Summary

Sr. No.	Hypothesis	Status
01	**H_1A:** There is a relationship between household solar panels and a decrease of energy crises	**Accepted**
02	**H_2A:** There is a relationship between the decrease in energy crises and the sustainable economic growth of Pakistan	**Accepted**
03	**H_3A:** Decrease in energy crises mediates between the use of household solar panels and sustainable economic growth of Pakistan	**Accepted**

5. CONCLUSION & DISCUSSION

The findings of the study reflected that the installation of solar panels on rooftops is significantly associated with a decrease of energy shortfall. In fact, the impact of the use of solar PVs on roofs is indirectly associated with the sustainable economic growth of the country. Therefore, the use of solar PVs is consistent with the indication of Rafique and Rehman (2017) who indicated that by 2050 demand for energy will increase by 300%. Thus, the creative use of natural resources is found to be valid for diminishing the energy crises of the country. Thus, the postulate made by Rafique and Rehman (2017) and Raza et al (2020) about the potential of renewable energy sources in Pakistan also seems to be valid and well-perceived by inhabitants. In fact, analysis of the questionnaire also reflected that inhabitants of urban areas of the country are willing to install solar PVs and this may be because of the substantial decrease in the prices of solar PVs as mentioned by Rahut et al. (2016). Thus, the overall ratio of electricity has been decreasing as indicated by Wittenberg and Matthies (2016), which also reflected that the use of solar PVs is substantial for sustainability or the environment and economy. Hence findings are also found to be consistent with the indications of Irfan et al (2019) that the use of solar energy is not only a way to diminish the cost burden but also for the betterment of the environment by minimizing the impact of pollution.

Moreover, the study is based on the use of rooftop solar PVs in Karachi city and the selection of the sampling frame is also found effective as the use was substantiated by Gautam et al (2015) which reflected that urbanization is the major reason behind the increase in electricity consumption. The study highlighted that inhabitants of these areas are now considering changing their shift towards the use of renewable energy resources. Especially for the developing sides of the world use of solar energy is perceived as much more important to reduce any economic, environmental as well as climatic hazards (Fauzi et al., 2023).

6. POLICY IMPLICATIONS

Based on findings from this study, it has been clarified that the use of solar panels at homes can decrease energy shortfall. Hence indirectly may also result in sustainable economic growth. Thus it is also required that the

government develop proper policies to provide subsidies for the purchase of household solar panels as indicated by Kabir et al. (2018). Moreover, the government must also devise some proper policies for using blockchain technology in digital routers for the smooth exchange of energy. A similar was indicated by the study by Tanaka et al (2017), thus legitimate to consider these points in making the most of the opportunity that inhabitants of Karachi have due to the mass availability of sunshine (Raza et al., 2020 & Yousuf & Siddiqui, 2018).

7. RECOMMENDATION & FUTURE DIRECTION

In light of detailed statistical testing, conclusion, and policy implications it has been recommended that home-based PVs must be used by Inhabitants of Karachi and other urban areas to help the government in managing the shortfall of electricity. A similar was indicated previously by Irfan et al. (2019) but there is a need for proper and adequate policy from the government to optimize the installation of on-roof solar PVs. Similar sort of indications was made by Alqahtani and Balta-Ozkan (2021). These points will be significantly important for a decrease in electricity bills & provide a sense of social responsibility by which inhabitants from urban areas may help their countrymen living in rural areas. However, further studies might be conducted in order to assess the impact of the installation of solar PVs on the decrease of pollution, the ability to shift electricity focus towards production and rural areas, etc. Similarly, studies associated with the installation of the on-roof solar PVs may also assess associated hurdles and challenges.

Appendix A

Questionnaire

Use of In Hours Solar Panels (Alsabbah, 2019) and (Faiers, & Neame,, 2006).		
1	Installing residential photovoltaic technology is possible in Pakistan	
2	Residential photovoltaic technology is easily available	
3	Residential photovoltaic technology reduces the electricity bill	
4	Residential photovoltaic technology is easily repairable	
Decreasing Energy Crises (Maxim et al., 2022); (Faiers, & Neame,, 2006).		
1	Use of Solar PVs in household systems are Safe form of power generation	
2	Decrease in energy crises resulted in decrease of electric load-shedding	
3	Use of solar Household PVs help work electric grids wor efficiently	
4	Use of Solar PVs in household systems may be further optimized in future	
Sustainable economic growth (Maxim et al., 2022)		
1	Decrease in energy crises resulted in increase of employment	
2	Decrease in energy crises resulted in decrease of pollution	
3	Decrease in energy crises resulted in increase of budgets for rural communities	
4	Decrease in energy crises resulted in Reduces carbon emissions	

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