

## Return on Investment (ROI) Analysis of OFF-Grid Solar Photovoltaic System in Residential Sector of Pakistan

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### Abstract

Pakistan being a developing country is observing a rapid rise in electricity demand and currently the big cities such as Karachi, Quetta, Rawalpindi and Lahore are most severely affected by the recent power crises. Therefore, at this time it is important to explore and investigate the alternate and renewable power sources in the country. This study investigates the significance in terms of economic feasibility of off-grid solar photovoltaic systems in the residential sector of Pakistan. Study area comprises the rural and urban residential sector of all four provinces of Pakistan. The return on investment and project payback periods are calculated using the NEPRA defined electricity tariff inclusive of tax so that a concrete conclusion of investing in off-grid solar could be drawn. Results of this study show that most selected areas in Pakistan have sufficient solar radiation potential for electricity generation. Study finds that solar electricity in Pakistan is one of the cost effective and environmental and social friendly forms of electricity. Payback periods of photovoltaic system in Sindh, Baluchistan, Punjab and KPK have been calculated 3.98, 2.33, 3.99 & 6.78 years, respectively. Results of this study may be useful for collective as well as individual consumers while calculating the economic viability of an off grid solar system.

**Keywords:** Photovoltaic System, Solar potential, Electricity, Off-Grid Solar System, Return on investment, economic feasibility, Pakistan.

### 1. Introduction

Energy plays a significant role in social and economic development by improving existing conditions (Ashfaq et.al., 2018). However, around 1.1 billion people in developing and developed countries lack or have no access to electricity (Dorman et.al., 2020). Most people suffering from this situation live in rural areas of sub-Saharan Africa and South Asia. The International Energy Agency (IEA) estimates that between now and 2030, the world's main energy sources will grow at an annual rate of 1.5%. Similarly, a substantial proportion of Pakistanis live in rural areas, and most of them do not have access to electricity. Currently the Pakistan is facing multiple social, economic, and environmental issues and challenges. Demand for electricity and energy is rapidly increasing in Pakistan mainly due to population increase and lifestyle changes. The country's overall electricity demand is 25,000 megawatts (MW) and is anticipated to boom to 40,000 megawatts by 2030 (Rehman et.al., 2017). Power supply continues to be around 17,000 MW, which translates into a power shortage of 8,000 MW in the country (Raheem et.al., 2016). The results show that the power outages in rural and urban areas are from 12hr to 18hr every day (Mirjat et.al., 2017). In addition, the conditions in the far-flung rural areas of Sindh province are so poor that electricity unavailable for many days.

Pakistan has huge energy potential, including oil, coal, natural gas, and renewables (wind, solar, biomass and hydro). The approximate potential for generating solar power is 2,900 gigawatts (GW), wind power (346 GW), hydroelectric power (6 GW) and biomass (5 GW) (Solangi,2019). Sindh province also as abundant sources of

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renewable energy which should be harnessed for electric power generation (Xu et.al., 2019). However, many rural areas are lacking in electrical installations. 48% of Sindh's population lives in rural areas, and approximately 13,451 villages have no electricity [10]. These villages are spread out far from nearest power grid, that is why connecting to the grid is not cost effective rather very expensive (Bhutto et.al., 2012). It is expensive to provide a grid-connected transmission for these villages, so in the near future, the possibility of grid-connected electricity is exceedingly small. Similarly, electricity produced by diesel operated generators is not a cost-effective option including the oil transport expenses which is hazardous to the environment as well.

In this case, photovoltaic solar energy is considered to have several benefits: the system offsets energy costs, reduces environmental impact and carbon dioxide emissions, and contributes to energy independence (Akella et.al., 2009). Large areas of Pakistan's Sindh, Baluchistan and Punjab provinces are barely cloudy for most of the year. Many research studies have proposed the off-grid solar photovoltaic systems as a suitable option for rural electric supply (Islam et.al., 2018). The photovoltaic solar system is greatly beneficial for the environment having no acoustic impact, reduces carbon dioxide emissions, and no impacts on the health of human and ecosystems (Hosenuzzaman et.al., 2015). Planning is the most important aspect of energy management and sustainable development (such as society, environment, and economy) (Awan et.al., 2014). Due to the above factors, hybrid, or off-grid solar is the best choice for power production in most residential areas of Sindh (Irfan et.al., 2019).

### 1.1 Pakistan Energy Mix & Solar Potential

Pakistan has an anticipated solar capability of 2,900 GW, but this renewable power remains waiting to be used (Harijan et.al., 2015). Figure 1 shows that the highest proportions participating in power generation are 33.6% for natural gas, 32.1% for oil, 26.1% for hydropower, 5.7% for nuclear power, 2.2% for renewable energy, and 0.2% for coal (Yearbook et.al., 2017).

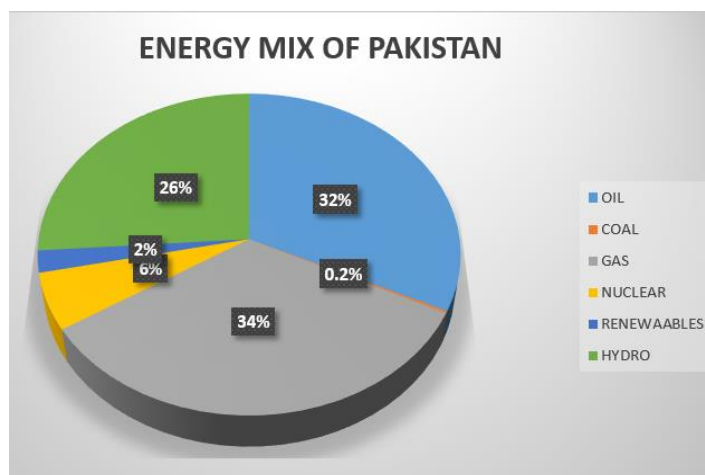


Figure 1. Energy mix of Pakistan.

### 1.2 Electricity Background-Sindh Province

Area wise the Sindh province is at number three in Pakistan accommodating the second largest population of the country (Wilderspin et.al., 2019). Because of its large coastal area, the province of Sindh enjoys a very strategic position as shown in Figure 2. Karachi Port also provides the best, cheapest and shortest route to transit cargo to neighbouring countries. The location of the port is particularly important, which is why it fascinates many national

developmental projects and overseas investment contributing to commercial and financial growth in Pakistan (Kazmi et.al., 2016). As a result, ongoing projects have rapidly increased the electricity demand in Sindh.

Sindh province as significant potential of wind, solar, biomass as well as small hydropower generation. However, despite the increasing demand for electricity, the Sindh provincial government has not taken seriously the issues related to the development of renewable energy. A draft renewable energy policy had been developed by the Sindh government in 2006 however, it is still facing many implementation constraints. Foreign as well as the local Investors are agitating to invest in far off rural areas due to political insecurity, poor law and order situations and risk on investment. (Xu et.al., 2019).



**Figure 2.** Sindh Province, Pakistan [22]

The increasing demand for energy has led to a huge power shortage in the country, which eventually led to an increase in electricity prices (Khalil et.al., 2014). Sindh province is highly affected by the increasing power deficiency facing the power outages of 2 to 17 hours a day (Bhutta et.al., 2018). In the far-off rural area of the Sindh, the situation of electricity is very worse facing the power load shedding of many days and weeks.

Low electricity consumption and locating the power transmission lines away from rural areas are one of factors contributing to high cost and less power supply in rural areas of Sindh.

### **1.3 Electricity Background-Baluchistan Province**

Baluchistan province has abundant resources of gas, oil and coal however these are not properly being harnessed to produce electricity. There are many reasons for less electric facilities in the province. About 90 % population living in rural areas do not have access to proper electricity (World Bank Group. (2016). The villages are located far away from each other having low population. Therefore, it is very costly to connect them with electricity facilities. Second, rural homes have an incredibly low power requirement at 50-100 W. Lighting is the only requirement for houses in rural areas, which are typically one-room cottages with adobe and thatched walls and roofs.

Therefore, extending the electricity transmission facilities is practically very costly in these areas. generators are also not an economical alternative due to the I cost of transportation. Finally, investors are reluctant to invest in rural Baluchistan because it is remote, the province lacks infrastructure, and energy-related data is not available for certain areas.

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Considering these factors, Off-grid solar energy is the best opportunity to produce energy in the rural areas of Baluchistan, as the province receives considerable amounts of solar radiation in its huge countries (Sadiqa et.al., 2018). The World Bank reported in its assessment of Pakistan's solar energy that all Baluchistan is rich in solar power potential and has plentiful sunshine ours in the world (Tahir et.al., 2018).



**Figure 3.** Baluchistan Province, Pakistan [<https://www.google.com/maps>]

#### **1.4 Electricity Background-Punjab Province**

Punjab, the land of the 5 rivers, the most populous and once known as the breadbasket of the east, is Pakistan's livelihood. However, poor people spend lot of money (about 25% of te total household budget) on alternate sources of electricity such as UPS, batteries, diesel etc. The unannounced power outages in Punjab have also peaked due to electricity shortages.

Citizens say that daily electricity shortfall last six to eight hours in most cities in Punjab, including Lodharan, Bahawalpur and Bahawalnagar, while in rural areas it lasts 10 to 12 hours and sometimes up to 16 hours. Asian development bank launched clean energy access program in Pakistan in 2016. The program is targeted to advance availability to energy for the communities in selected districts of Punjab and Khyber Pakhtunkhwa (KPK) in Pakistan by exploiting available clean energy resources whose potential already exists in Punjab and KPK.

#### **1.5 Electricity Background-KPK Province**

Khyber Pakhtunkhwa is the land of hospitality, fascinating landscapes, extensive culture, amazing history, legendary conquerors, and a centre of tourism. The province is in the northwest of the country. The total area of the province is 101,741 km<sup>2</sup>. The province has 35 million inhabitants, of which 52% are male and 48% are female, which is 11.9% of the total population of Pakistan.

The literacy rate for the province is 53%. It is the third literate province in Pakistan. The youth of the province is complemented by a broad vision and innovative ideas for transforming the province. The government equips them with usable skills to develop their potential. About 50% of the population of Khyber Pakhtunkhwa are young. Statistics show that the province, which comprises the majority of young people, has enormous potential to contribute to a prosperous country. However, the limiting factor is the electricity and sources say that the load shedding is currently being carried out based on the shortfalls of 5,500 MW in KPK, Sindh and Baluchistan and an additional 1,500 blackouts are announced. For this reason, people in KPK, Sindh and Baluchistan and some

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areas in southern Punjab suffer badly from a massive 4–20-hour electricity loss and many suffer a massive 6-10-hour load loss in Peshawar (Saleem et.al., 2022).



Figure 4. Punjab Province, Pakistan [<http://www.google.com/maps>]



Figure 5. KPK Province, Pakistan [<http://www.google.com/maps>]

## 1.6 Photovoltaic Systems

Solar photovoltaic systems (solar photovoltaics) are used in large-scale and residential environments to convert sunlight into electricity. These systems consist of modules containing semiconductor materials that can absorb photons from the sun to generate electricity (Knier et.al., 2002). As a renewable energy source, solar photovoltaic systems are becoming increasingly common in the world (Solar Energy Industries Association, 2016).

Solar photovoltaic systems can be utilized as off grid, on grid and hybrid systems.

**1.6.1 Off-grid solar systems** or Autonomous solar photovoltaic systems are independent systems that can operate without being connected to the main grid. The extra energy produced by the solar system is stored in the battery. This type of system comprises solar modules, battery packs and off-grid inverters (Kempener et.al., 2015).

**1.6.2 On-grid solar systems** there is no battery pack for storage. Solar energy is the main source and network used. With net metering, additional power can be injected into the main grid. The system is only used for power generation and consumption during the day. For night consumption, battery packs can be used to save energy

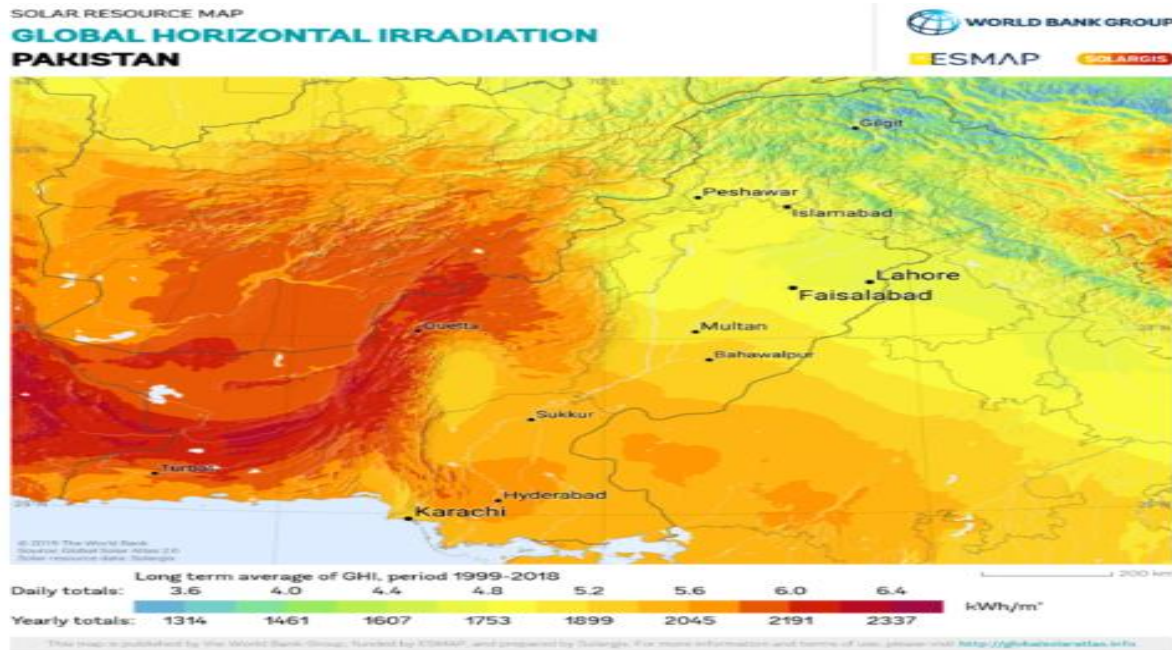
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generated during the day, which will eventually increase the initial cost of the system. Therefore, a spare battery is not needed during the day (Moradi et.al., 2017).

**1.6.3 A hybrid solar system** is the combination of off-grid solar system and On-grid solar system, where the main energy is solar energy, and the excess energy is stored in the battery power supply/back-up; when the storage capacity is full, the additional energy enters the main network through net metering (Ingole et.al., 2015).

### 1.7 Solar Potential of Sindh Province

The Sindh province as ample amount of sunlit available throughout the year. (Irfan et.al., 2019) as also seen in figure 6.



**Figure 6.** Pakistan Global Horizontal Irradiation Map (Brent et.al., 2020)

Also, since the latitude positions of these areas are in the 25-30 N range, the sunlight is expected to be remarkably high. The mean annual solar peak hour in a large area of Sindh province is up to 5.44 hours. The province's solar energy potential is huge, the amount of sunlight is high, the number of sunny days exceeds 300 days, and the global annual irradiation level is about 1800-2200 kWh / m<sup>2</sup> (Wakeel et.al., 2016). In addition, the Asian Development Bank recommends that off-grid solar photovoltaic (PV) be the best option due to its ease of installation, low cost, and better socio-economic conditions in rural areas. (Shah et.al., 2018). The World Bank had also announced that it will provide a loan worth US\$100 million to clean energy facilities in Sindh. The goal is to provide off-grid solar photovoltaic power to 200,000 households, equivalent to 1.2 million people (Xu et.al., 2019).

### 1.8 Solar Potential of Baluchistan Province

Baluchistan province as very significant number of solar radiations as compared with other provinces of Pakistan with mean daily solar radiation of about 5.9-6.2 kWh/m<sup>2</sup> /day in the province (Adnan,2012). The province has an annual average sunshine period of 8- 8.5 hours with an average daily world-wide insolation of 19 to 20 MJ/m<sup>2</sup> /day (Muhammad et.al., 2017). The World Bank reported that all of Baluchistan is abundant in solar energy with highest average hours of sunshine in the world (World Bank Group ,2016). According to the report, northern parts

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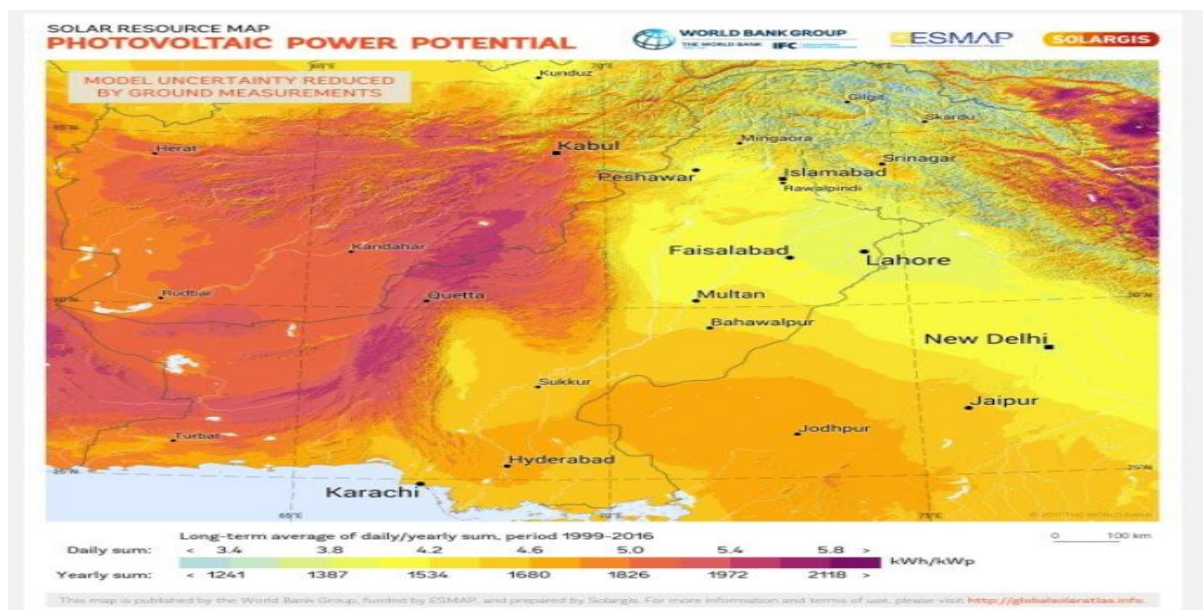
of the province, with peak direct normal irradiance (DNI) value of 2700 kWh/m<sup>2</sup>, are the most desirable for solar energy generation (Bhutto, 2016). In many areas of Baluchistan Off-Grid PV systems are already in use including Uthal, Jhal Magsi, Zhob, Hub, Sibi, Khuzdar, Loralai, Sherani, Khanozai, Panjgur, Chaman, Kalat, Pishin, Dhadar, Bolan and Duki Baluchistan. These solar. Solar power yield may be extended by 10.78 to 30 % in Baluchistan province on an optimal tilting angle of 30.3° (Shah et.al., 2018).

### 1.9 Solar Potential of Punjab Province

Identification of solar potential is very critical for any solar based facilities. (Kharseh et.al., 2018). As per a research, results revealed that Punjab has an immense potential of Off-Grid PV Panels and that the maximum annual solar irradiation was established by Khanewal region 5.50KWh/m<sup>2</sup> whereas Bahkar Region received 5.46 KWh/m<sup>2</sup>, Bahawalnagar, Rajanpur regions receive annual solar irradiation of 5.41 and 5.37 KWh/m<sup>2</sup>. Besides the average solar irradiation values, Average Peak Solar hours for these regions are 5.434 hours. The off-grid solar PV system may prove a good option for electric energy generation in Punjab. (Kharseh et.al., 2018).

### 1.10 Solar Potential of KPK Province

In Figure 7, the average GHI is 1800 kWh/m<sup>2</sup> in northern regions (KPK and upper parts of Punjab province). Solar energy availability is not high and flat land is rare in the region (Soomro et.al., 2019). In KPK solar radiation varies as (4.0-5.5) kWh/m<sup>2</sup> /day (Raiz, 2014).



**Figure 7.** Pakistan Photovoltaic Potential Map [Brent et.al., 2020]

From Figure 7, we can see that Daily sun in KPK region varies from 3.4 to 4.2 hours and therefore average peak hours are 3.8 hrs and varies as per sky clearance.

### 1.11 Return on Investment Analysis

The ROI calculation organizes the project costs and benefits into a useful profitability indicator [33-59]. Return on investment is the most common measure of value-added income. Compare the monetary benefits of the plans with the costs of these plans. Traditionally, ROI has focused on a historical review of investment success;

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however, it is often used to predict the potential performance of an investment plan or project (Phillips et.al., 2012). Some initial studies on the EROI of solar photovoltaic systems have led people to believe that solar photovoltaic technology is inferior to other energy sources (such as coal and natural gas) and is not a viable energy option (Raugei et.al., 2010). However, the data used in these early studies is now out of date because the efficiency of solar PV modules has increased and the efficiency of its manufacturing process is also greatly increased (Bhandari et.al., 2015).

Before installing a solar PV system, the owner must accurately estimate the return on investment (ROI) to determine if it is truly a promising investment compared to using standard electricity (Hay, 2016). The return on investment is the gain earned from the investment. In this case, compared to standard electricity, the amount saved by using a solar photovoltaic system divided by the initial start-up cost (Hossain et.al., 2019).

This research aims to provide in depth calculation of return on investment of off-grid solar photovoltaic system and comprehends if investing in solar PV system is economically beneficial for residential consumer of each province or not.

## 2. Materials & Methods.

Present study is based on both primary and secondary data sources. Kilowatt or load details used in this study for residential small to medium households in Pakistan is taken through unstructured interviews. Interviews were conducted by means of in-person meeting, social media and through telephonic conversations. The process was initiated through interviewing relatives and friends living in Karachi and other major cities of Punjab, Baluchistan and KPK. In addition, public places were visited and general public at those locations were interviewed to further know the diverse nature of load installed in small to medium homes in Pakistan.

Cost of Solar System installation along with all related material including Solar Plates, Power Inverter, Battery Bank, Copper Wiring, Mounting Structure, Distribution Box, AC & DC Circuit Breakers, Switches Transportation, and installation charges details were taken through market research and by contacting the suppliers by means of visiting the designated place in Karachi and through telephonic conversation with the stakeholders involved in PV Systems parts and installation.

### 2.1 Assumptions

1. Electricity tariff is taken in accordance with NEPRA for all provinces.
2. This study does not include large residential and commercial or industrial sectors.
3. Grid line losses are not considered during the entire study.
4. Taking 30 days in a month in calculations.

Following equation was used to calculate the per day energy output from 3.2 KW PV System

$$\text{Energy output per day} = PV \text{ Efficiency} \times PV \text{ Installed Capacity} \times \text{Average Peak Solar Hours} \quad (i)$$



Following equation was used to calculate the per month energy output from 3.2 KW PV System

$$\begin{aligned} \text{Energy Output per month} \\ = (PV \text{ Efficiency} \times PV \text{ Installed Capacity} \times \text{Average Peak Solar Hours}) \times 30 \end{aligned} \quad \text{(ii)}$$

### Monthly Monetary Return

Next step will be to calculate monthly monetary return as per NEPRA [58] defined tariff for all provinces of Pakistan.

### 2.2. Payback Period Calculations

Following equation was used to calculate the payback period;

$$C - ND = 0 \quad \text{(iii)}$$

or

$$N = \frac{C}{D} \quad \text{(iv)}$$

Where  $C$  = System Cost in PKR,  $D$  = system saving per month in PKR and  $N$  = No. of month

Payback period is calculated using the monthly monetary data of each province which is directly dependent on solar hours of each province. All Statistical data and analysis is carried out using Microsoft excel and all report and writing activity is carried out using Microsoft word.

### 3. Results & Discussions

It is noted from Table 1 that the results of survey revealed that in Pakistan average residential sector consumer load is below 3.2KW. Hence, the results show that an average residential consumer whether maybe living in Sindh, Baluchistan, Punjab or KPK can easily power all their electrical equipment and appliances that are mentioned in table 01 by incorporating a 3.2 KW solar panel system on their roof top.

**Table 1.** Average household load details in Pakistan.

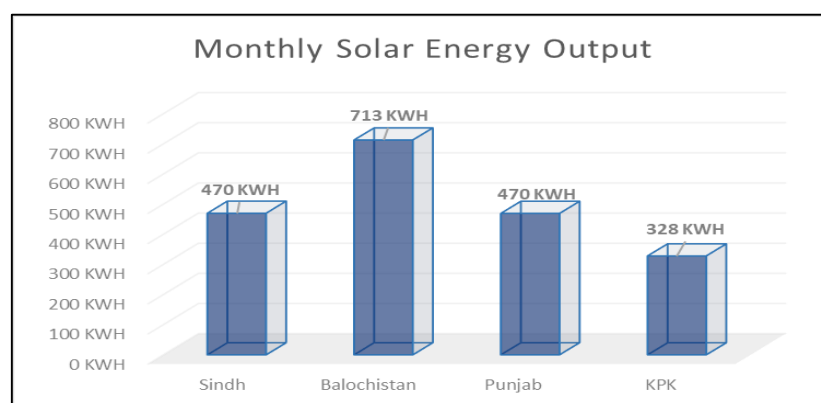
<i>Equipment</i>	<i>Qty</i>	<i>Watt</i>	<i>Total Watt</i>
<i>AC 1 Ton Inverter base</i>	1	900	900
<i>Fridges</i>	1	450	450
<i>LED TV</i>	2	150	300
<i>Lighting Load</i>	15	35	525
<i>Fan, Exhausts</i>	8	120	960
<b><i>TOTAL</i></b>			<b>3135</b>

Table 2 reveals the results of the market research survey carried out for 3.2KW solar panels. The net amount includes installation commissioning and transportation. The detailed quotation of 3.2KW solar package along with materials and quantity is enlisted in Table 2. The approximate price of investment in any province is more

or less equal to four hundred nine thousand only. The survey data is further used in calculation to know the cost benefit analysis of 3.2KW PV system in Sindh, Baluchistan, Punjab and KPK, respectively.

**Table 2:** Market Survey & cost details of 3.2KW PV system

<i>Item Details</i>	<i>Specifications</i>	<i>Qty/Job</i>	<i>Net Amount</i>	
<i>System Details</i>	3.2 kW Package	Solar Module: Mono PERC Half-Cut Brand: Inverex/ Trina Solar/Longi/Jinko/JA Wattage: 400-550 Watts	6-8	409,000/-
		Intelligent Inverex Aerox Plus/iii/veyron 3.2 KW 24V	1	
		Inverex/ Phoenix /Exide / Osaka Tall Tubular Deep Cycle Batteries (200-250Ah)	2	
	PV Balance of System	High quality Distribution Box	1	
		DC Breakers	2	
		Selector Switch	1	
		AC Breakers	2	
		Battery Cable - 25mm	6m	
		PVC Electrical Cable	200 ft	
	Solar Panel Structure	Ground Mounted Structure	4	
Installation Charges	Designing, Installation and Commissioning charges Included	1		
Civil Work	Standard Civil Pads Included	1		
Transportation	All across Pakistan			
Total Price (Rs.)	Rupees Four Lacs and Nine Thousand Only		409,000/-	



**Figure 8.** Province wise Solar Energy Potential

Solar peak hours in Sindh, Baluchistan, Punjab & KPK are 5.4hrs, 8.25hrs, 5.43hrs & 3.8hrs respectively and are taken from Solar Resource Map provided by The World Bank Group also seen in Figure 6 & 7. Energy potential, daily and monthly of each province used in this study is calculated using Equation (i) & (ii) respectively, the

monthly energy potential data of each province can be seen at Figure 8. It is also revealed from Figure 8 that the energy potential on Sindh and Punjab is more or less the same whereas Baluchistan has the highest solar energy potential and KPK has the least mainly due to few solar peak hours as also seen in Figure 7.

Cost Savings analysis for each province is done as per NEPRA defined Electricity Tariff structure as seen in Figure 9.

A1- Residential										
Description	Fixed Charges	Notified Tariff	* Industrial Support Package	Qtr. Adjust. for 1st & 2nd quarter, Notified	Qtr. Adjust. for 3rd & 4th quarter and interim increase on account Distribution Margin, notified w.e.f. 01-10-2019	Quarterly Uniform Tariff 1st QTR 2019-20 w.e.f. 01-12-2019	Total Applicable Tariff	Monthly FCA for October 2019,	Total	
		01-01-2019	w.e.f. July 01, 2019	w.e.f 01-07-2019				charged in		
		Variable Charges						Variable Charges		January
		Rs./ kW/M			Rs./kWh			Rs./kWh		2020
A	B	C	D	E	F	G= B+C+D+E+F				
Up to 50 Units		2.00					2.00		2.00	
For peak load requirement less than 5 kW										
01-100 Units		5.79				-	5.79	1.57	7.36	
101-200 Units		8.11				-	8.11	1.57	9.68	
201-300 Units		10.2				-	10.20	1.57	11.77	
301-700Units		17.6		0.75	0.83	0.07	19.25	1.57	20.82	
Above 700 Units		20.7		0.75	0.83	0.07	22.35	1.57	23.92	
For peak load requirement exceeding 5										

Figure 9. NEPRA defined A1-Residential Tariff

Table 3: Electricity Savings Calculations for each Province

Cost Savings Per Month in Sindh

Variable Charges	Solar Energy output (KWH)	Rate/Unit/%	Total
201-300	300	12	3,531
301-700	170	21	3,539
Above 700		24	
		Total Excl. Tax	7,070.40
GST		17%	1,201.97
TVL Fee (Fixed)			35.00
FC Surcharged		0.43	202.10
NJ Surcharged		0.1	47.00
		Net Saving	8,556.47

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### Cost Savings Per Month in Balochistan

Variable Charges	Solar Energy output (KWH)	Rate/Unit/%	Total
201-300	300	11.77	3,531.00
301-700	400	20.82	8,328.00
Above 700	13	23.92	310.96
Total Excl. Tax			12,169.96
GST		17%	2,068.89
TVL Fee (Fixed)			35.00
FC Surcharged		0.43	306.59
NJ Surcharged		0.1	71.30
Net Saving			14,651.74

### Cost Savings Per Month in Punjab

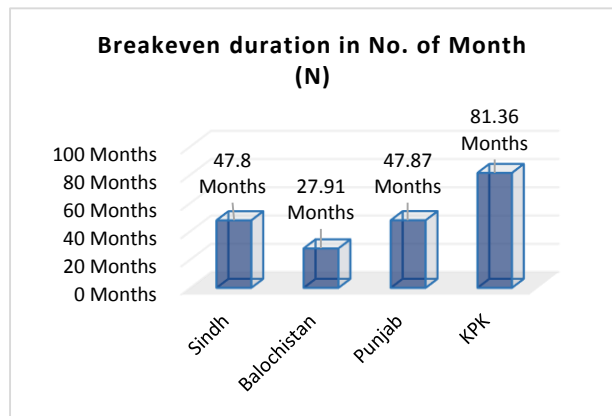
Variable Charges	Solar Energy output (KWH)	Rate/Unit/%	Total
201-300	300	11.77	3,531.00
301-700	169.5	20.82	3,528.99
Above 700		23.92	
Total Excl. Tax			7,059.99
GST		17%	1,200.20
TVL Fee (Fixed)			35.00
FC Surcharged		0.43	201.89
NJ Surcharged		0.1	46.95
Net Saving			8,544.02

### Cost Savings Per Month in KP

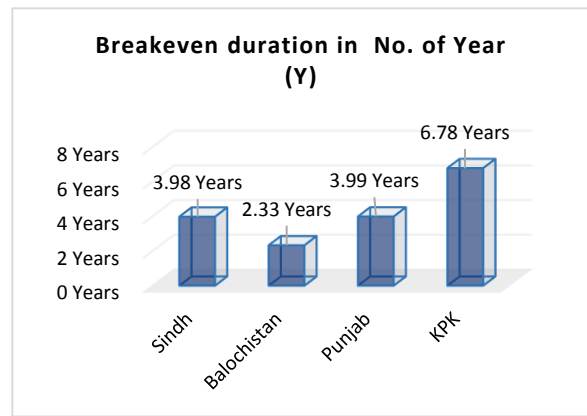
Variable Charges	Solar Energy output (KWH)	Rate/Unit/%	Total
201-300	300	11.77	3,531.00
301-700	28.2	20.82	587.12
Above 700		23.92	
Total Excl. Tax			4,118.12
GST		17%	700.08
TVL Fee (Fixed)			35.00
FC Surcharged		0.43	141.13
NJ Surcharged		0.1	32.82
Net Saving			5,027.15



After cost savings per month calculations monetary return or break-even duration is calculated using Equation (iii) or (iv). Figure 10 & Figure 11 reveals the results of breakeven duration in months and in years, respectively. Therefore, the cost of the overall project including installation can be paid back or recovered as per calculated months and after return on investment electricity generated will accounted as free of cost till the life of the system.



**Figure 10:** Return on Investment in Months



**Figure 11:** Return on Investment in Years

#### 4. Conclusions

Off-grid solar photovoltaic systems are considered the best option to provide electricity to both rural and urban residential areas of Sindh, Baluchistan, Punjab and KPK provinces of Pakistan. This study successfully assessed the technical and economic feasibility of installing a 3.2 kW off-grid solar system in Sindh, Baluchistan, Punjab and KPK residential sector. Study concludes that off-grid solar photovoltaic systems besides their technical viability will also help reduce carbon dioxide and other greenhouse gas emissions produced from conventional sources of electricity such as fossil fuels. It is also concluded that compared to other traditional energy sources, off-grid solar PV systems are a cheaper option for electricity and their return on investment can be achieved within 3.98, 2.33, 3.99, 6.78 years in Sindh, Baluchistan, Punjab and KPK, respectively. The study determined that Sindh, Baluchistan, Punjab, KPK has good solar energy potential, and it is technically and economically feasible to use solar energy for residential purposes in these areas. Therefore, the government must plan and establish a robust policy framework to install and support off-grid solar systems throughout the Pakistan.

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