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COST BENEFIT ANALYSIS OF ON-GRID SOLAR PV SYSTEM FOR AN INDUSTRIAL SETUP OF PAKISTAN

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Abstract

Pakistan is facing severe energy crises due to a significant increase in demand with increasing residents and development of the cities. With its crumbling economy it does not have enough resources to manage the import bill. Because of this energy resources deficit, it has failed to meet this growing demand of electricity in the country. This electricity shortfall is causing industries of the country to close their operations and move to other countries in the region. Renewable energy plays an important role in such an energy crisis by producing alternative energy that is greener and reduces the carbon footprint of the environment. The renewable energy sector i.e., solar, wind and hydropower is an active research area and there is a huge space for modern industrial units and commercial buildings to bridge the gap between electricity generation and energy demand in Pakistan. To void that gap, an on-grid solar system is proposed for a local textile mill in site area kotri, Pakistan. Solar photovoltaic (PV) potential 1 MW is proposed for the first phase and can be extended further. By installing solar system, the mill can save millions of rupees in bills to HESCO and play a role towards green environment by reducing green-house gases. This paper provides a cost-benefit feasibility analysis of the project and environment friendly effect of such projects on global warming.

Keywords: *Energy generation, photovoltaic, cost-benefit, feasibility, environment friendly*

INTRODUCTION

The world population has grown significantly as well as the living standards have also risen which results in increased energy and power demand specifically in developing countries (Tareen *et al.*, 2018). For any nation energy is essential for the economic development. Currently the primary source of electricity generation across the world is fossil fuels. The increased usage of fossil fuels in power generation sector not only adds financial burden but also increases the CO_2 emissions of the generation industry. The major drawbacks of these are fast depletion rates and serious environmental impacts caused by combustion process (Aziz *et al.*, 2020). Due to the scarcity of fossil fuels the electricity generation is affected badly. Therefore, Renewable energy resources become vital and effective solution for the reliable electricity supply to the consumers.

Despite the enormous energy resources Pakistan have, it is confronting severe electricity crisis (Mirjat *et al.*, 2017). This electricity crisis has led the agriculture, industry, and commerce etc. to

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decline. In the previous few decades Pakistan's economy and industrial progress has been adversely affected by the shortage of energy. The shortage of energy causes reduction in the production of industries and as well as unemployment in the country (Kashif *et al.*, 2020). Pakistan requires a massive amount of energy (Shakeel, Takala and Shakeel, 2016) and uninterrupted source of supply to make its industrial output and economic development on track and provide a reasonable standard of living for its population (Shakeel, Takala and Shakeel, 2016). Currently, Pakistan is heavily dependent on the nonrenewable energy resources such as Fossil Fuel, Oil, Coal and Liquified Petroleum Gas as a source of energy (Hakeem and Soomar, 2021). These resources are depleting rapidly therefore the World has moved towards renewable sources. These resources can also bridge up the current energy demand as well the future energy needs of Pakistan (Farooq and Kumar, 2013). Pakistan has just started transforming its energy sector by introducing renewable resources such as Solar energy, Wind energy, Hydal and Biomass but still it must go a long way, these resources are present in abundance in Pakistan, but have not been properly exploited yet. The current primary energy supplies of Pakistan are Oil, LPG, Coal, Gas, Hydro, LNG Import, and small number of renewable resources.(Soomar *et al.*, 2022) The figure 01 taken from the Pakistan Energy Yearbook 2019 depicts how different sources supply energy.

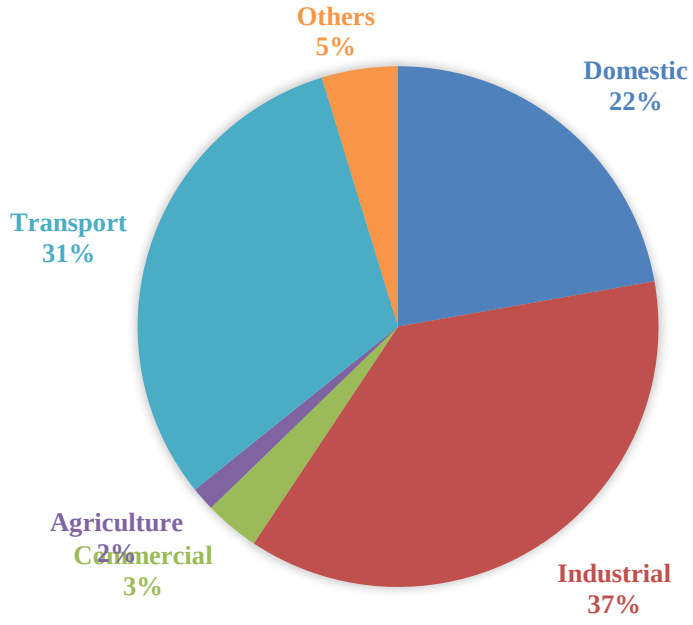

Figure 01: Energy Consumption of different Sectors (Energy, 2019)

There is a considerable rise in the usage of Renewable resources due to fall in import of fuel. The application of renewable resources will decrease the gap between the energy consumption and generation. The renewable energy will not only overcome the energy demand, but also excessive energy will be available for the coming years. The figure 02 shows that only 4 percent energy was supplied from renewables. Pakistan is blessed with number of energy resources which need to be utilized timely.

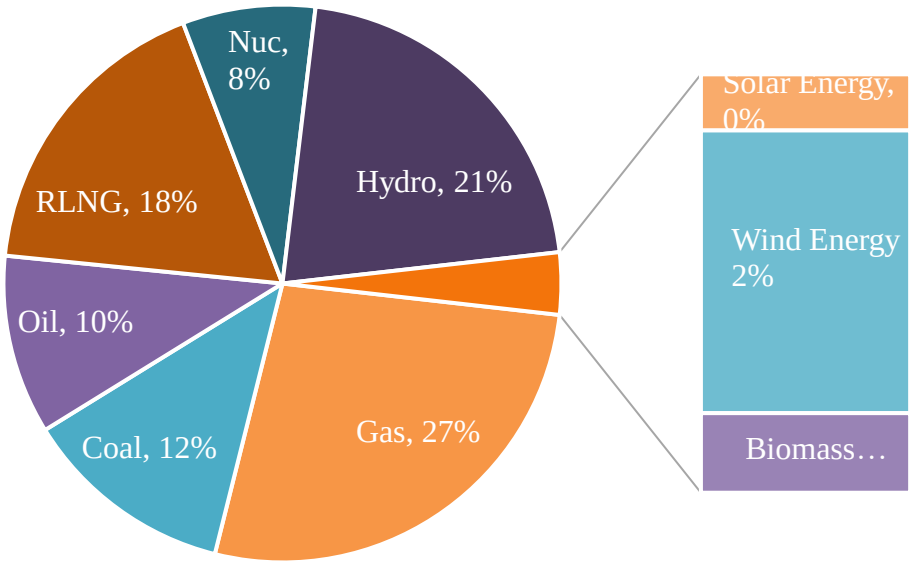

Figure 02: Electricity Generation 2018-2019 (Energy, 2019)

Pakistan is facing severe energy crises be it oil or gas, at this rate of energy depletion soon industries across Pakistan will be on the verge of closure which will not only affect the exports of Pakistan but will also create severe unemployment in the country. It is a high time that bigger names in Pakistan specially textile industries, because it is one of the major export industries, need to shift their focus on production of renewable energy for their own usage as well as supply to government if produced in surplus.

SITE ASSESSMENT REPORT

The local textile mill chosen for cost benefit analysis is situated in Site Area Kotri, Pakistan. It consumes its power from HESCO, and Gas turbine generators installed on site. The data collected for the past two years shows that the per unit cost is around Rs.20 for HESCO supply and Rs.10 for generators. Which is so expensive and non- environment friendly energy production. It can be overcome if solar system is installed in the mill, which is environment friendly and top source of energy generation in Pakistan because Pakistan is fortunate to have a high solar insolation of 6.52 $kWh/m^2/day$ at tilt angle of 30 degree towards south facing at an azimuth angle of 180 degree. (Solar energy, 2016)

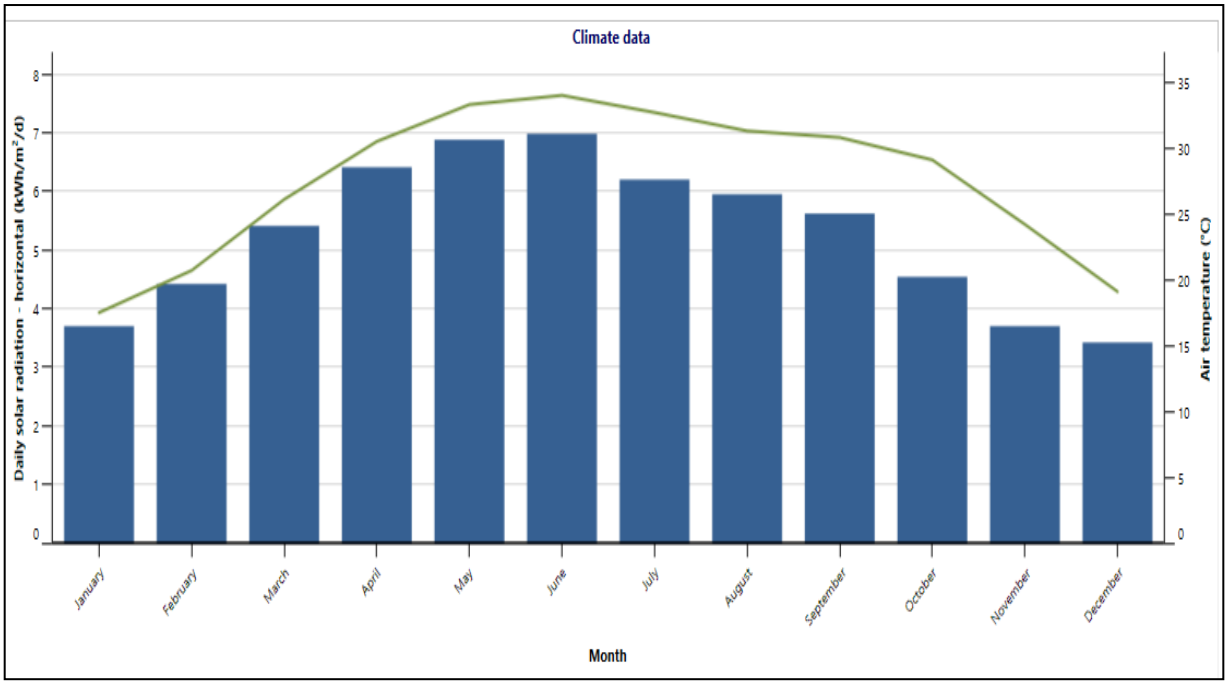

Figure 03: Solar radiation data of the site (Source, Nasa)

Figure 03 shows the monthly solar radiation data of the site. It is evident that the site receives the highest radiation of 7 kWh/m²/d in the month of June and it is above 6 kWh/m²/d for four consecutive months. i.e., from April till July. Overall, for whole year the radiation does not fall below 3.5 kWh/m²/d. This type of climate makes this site suitable to install a Solar PV system.

ECONOMIC ANALYSIS OF CONVENTIONAL SOURCES

The energy consumption of the past two years was obtained for both the sources, HESCO and Generators. Following table shows the analysis.

Table 01: Economic analysis of conventional sources of the mill

Description	HESCO	Generators
Units consumed in 2020-21 (GWh)	5.9	40.9
Average per unit cost for 2020-21 (Rs/kWh)	18.8	11.82
Units consumed in 2021-22 (GWh)	10.4	33.5
Average per unit cost for 2021-22 (Rs/kWh)	21.05	8.88

From the above table, it is evident that the mill is paying a large amount in bills to the HESCO, per unit cost in 2020-21 was Rs 18.8 and in 2021-22 was Rs 21.05. The total bill paid to HESCO in the past two years was 227 million Rs. Whereas, for generators per unit cost in 2020-21 was Rs 11.82 and 2021-22 was Rs 8.88 and operational charges were 77.2 million Rs. The major portion of the supply is provided through Gas and Diesel Generators. Moreover, the per unit cost for generators is half as compared to HESCO supply. HESCO is costing more so this should be targeted in the initial phase. Therefore, the Low-tension line of mill which is supplied by HESCO is chosen to be replaced by On-Grid solar power plant.

RESEARCH METHODOLOGY

It is evident from site assessment that a considerable potential of solar energy is available, this energy could be utilized to generate electrical energy. In this context research methodology shown in figure 04 is undertaken.

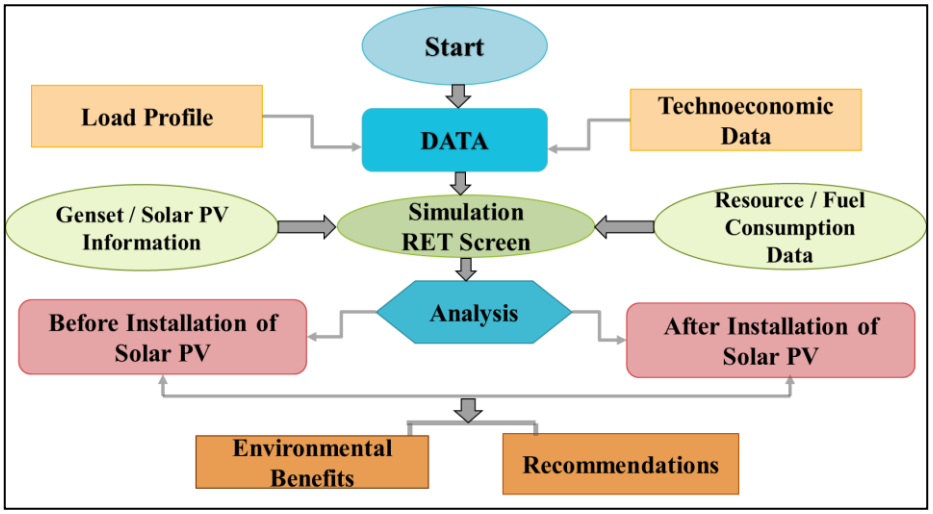

Figure 04: flow chart of research methodology

The load generation and consumption data of the conventional sources is obtained from the mill. After performing the tecno-economic analysis of the sources, the suitable injection point of solar power is selected to provide maximum benefit to the mill. Load profile and tecno-economic data of HESCO as well as Generators is given to RETscreen as an input. The feasibility of the project is discussed by analyzing the results obtained from the model. Also, based on the results the recommendations are formulated for other industries across Pakistan.

SOLAR POWER PLANT DESIGN CONSIDERATIONS

The load profile of LT line is shown in figure 04. Initially 1 MW plant is proposed on LT line. The Solar PV system can be installed on the roof tops of the Unit 1 and Unit 2 of mills.

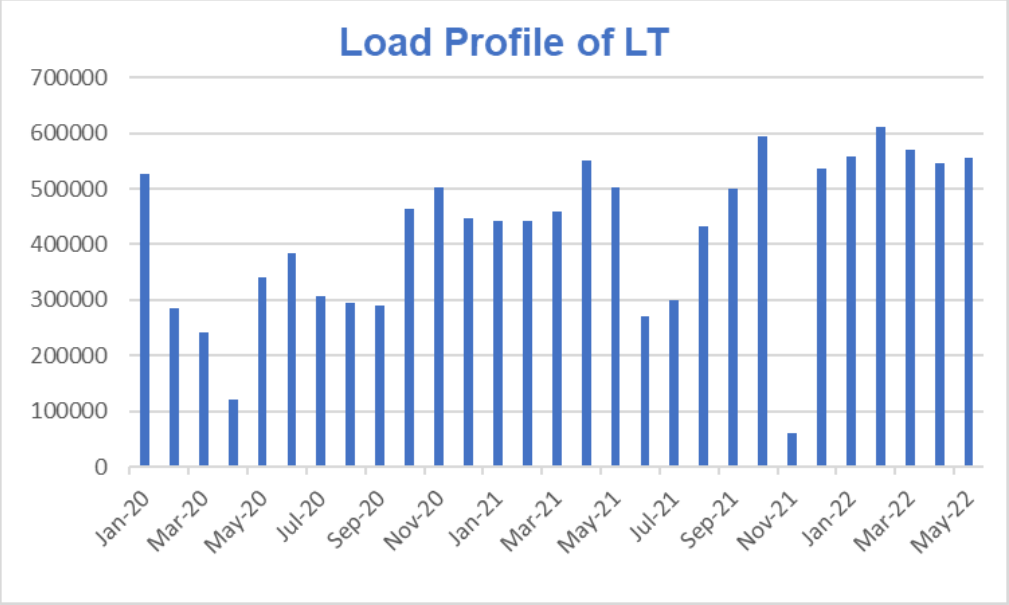

Figure 05: Load profile of LT line considered for Solar PV system

The figure 05 shows the graph of units consumed per month of LT line from January 2020 to May 2022. The graph shows that maximum demand reaches up to 600 MWh, while average energy consumed in the period is 457 MWh per month. Based on the load profile of LT, 1 MW Solar PV system combined with grid is proposed with parameters given in table 02 (NEPRA, 2020).

Table 02: Parameters selected for Solar Power Plant design

Type	On-Grid
Solar Panels	Mono-Crystalline
Wattage of Single Panel	535 W
Proposed Size of Power Plant	1 MW
Number of Panels	1847
Initial Cost (Rs/Watt)	76
Operation and Maintenance Cost (Rs/MW)	2 million
Capacity Factor (%)	17
Project Life (years)	25
Electricity Export Rate (Current) Rs/kWh	13
Cost Escalation (%)	5
Operation and Maintenance Inflation (%)	7

For the design of Solar PV system, mono-crystalline solar plates will be used each of 535 watts. Total 1847 plates will be used to generate 1 MW of power. Currently the electricity export rate set by NEPRA is 13 Rs/kWh. This price will increase by 5 % for the upcoming years, increasing the revenue Overall, project life is estimated to be 25 years. This data is used to analyze the feasibility of the project by using RETscreen software.

RESULTS DISCUSSION

Considering 1 MW solar PV system at Kotri site area has been modelled using RETscreen. Model results concluded the yearly units generated from solar plant are 1.5 GWh and earnings to be 19.3 million Rs, at the electricity export rate of 13 Rs/kWh.

Table 03: Technical details of the project

Description	Values
Power Capacity (MW)	1
Number of Units	1847
Capacity factor (%)	17
Initial costs (Rs)	76 million
O&M costs (Rs)	2 million
Electricity export rate (Rs/kWh)	13
Electricity exported to the gird in 1st year (GWh)	1.5
Electricity export revenue for the 1st year (Rs)	19.3 million

Table 04: Financial Analysis of the Project

Description	Values
Fuel Cost Escalation Rate (%)	2
Inflation Rate (%)	7
Discount Rate (%)	9

Reinvestment Rate (%)	9
Project Life (years)	25
Incentives and grants (Rs)	0
Debt Ratio (%)	70
Debt (Rs)	53.2 million
Equity (Rs)	22.8 million
Debt Interest Rate (%)	7
Debt term (years)	15
Debt Payments (Rs/year)	5.8 million

The finances considered for the project are shown in table 04. Inflation rate is 7%. Whereas project life is expected to be 25 years. Debt ratio is considered 70% and debt term to be 15 years. According to these, the yearly debt payments will be 5.8 million.

ECONOMICS OF THE PROJECT

To obtain an idea of how economical the project is, its economic analysis is performed using RETscreen software and the results given in table 05 are deduced.

Table 05: Cash flow for year-1 of the project

Initial cost (Rs)	76 million
Yearly cash flows- year 1	
O&M costs (Rs)	2 million
debt payment (Rs)	5.8 million
Total annual costs (Rs)	7.8 million
Annual savings and revenue	
Electricity export revenue (Rs)	19.3 million
Net yearly cash flow- year 1 (Rs)	11.5 million

Table 05 gives the net cash flow of 1st year of the project. The initial cost of the project will be 76 million Rs. The first-year costs will be 7.8 million Rs and first year's earnings from solar energy export will be 19.3 million. So, the yearly cash inflows after deducting the costs will be 11.5 million. At this rate the equity will be returned in merely 2 years.

FINANCIAL VIABILITY OF THE PROJECT

This financial viability of the project is discussed here, the payback period for the project is four and a half years which is considerably short. Whereas Equity payback is even less than two years. The energy production cost is only 7.49 PKR/unit. Which is less than that of the company is paying now (HESCO and Generators). Looking at the results this project will be beneficial for the industries.

Table 06: Financial viability of the project

Description	Values
Pre-tax IRR-equity (%)	60.9
Pre-tax MIRR-equity (%)	19.4
Pre-tax IRR-equity (%)	22.4
Pre-tax MIRR-equity (%)	13.8
Simple payback (years)	4.4

Equity payback (years)	1.8
Net present value (Rs)	199 million
Annual life cycle savings (Rs)	20.2 million
Benefit-cost (B-C) ratio	9.7
Debt service coverage	3.1
Energy production cost (Rs/kWh)	7.49 PKR/kWh

Yearly cash flows for the solar project are shown in figure 05, it is clear that for the 1st year the cash flow is negative after that its positive and increases with each passing year as the debt will be over after 15 years.

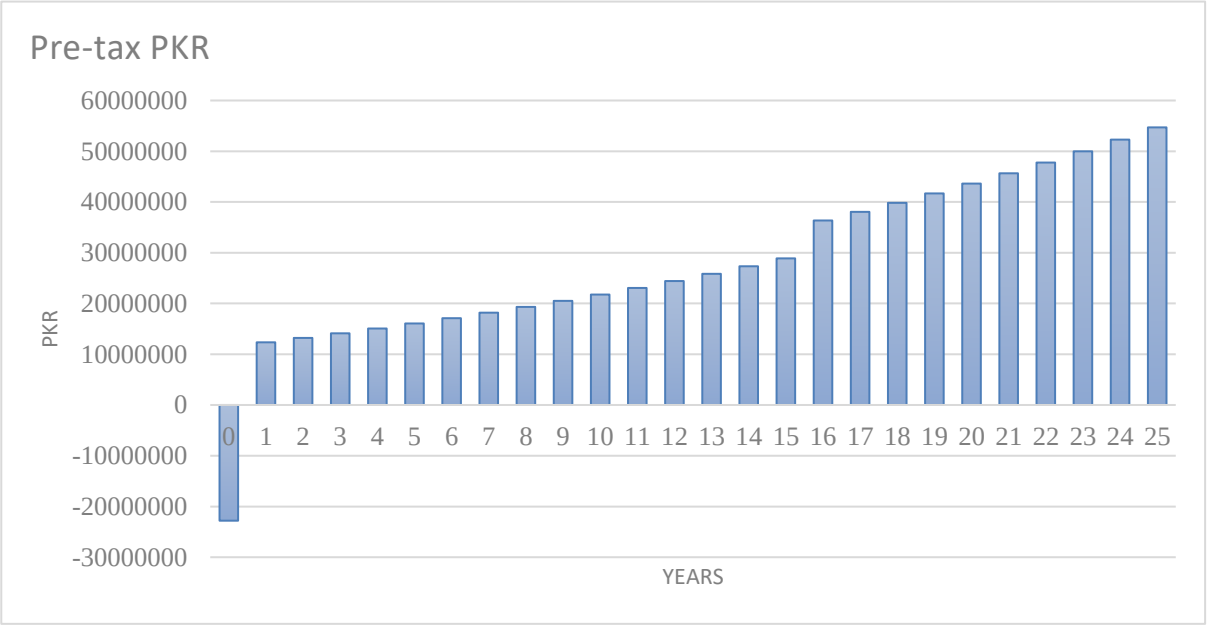

Figure 06: yearly cash flows of the project

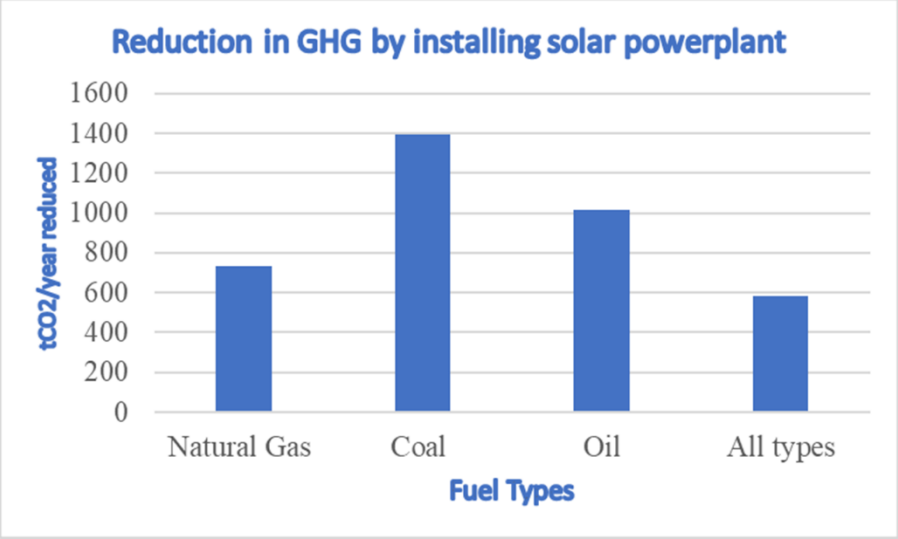

Figure 06: Reduction of GHG by installing solar powerplant as compared to different fuels

ENVIRONMENTAL BENEFITS OF THE PROJECT

The GHG reduction due to solar plant as compared to natural gas fuel type is found to be 732 tons

per year which is equivalent to 166 acres of forest plantation. 1396 tons of GHG can be reduced in the case to coal fuel type which is equivalent to 317 acres of forest plantation. Whereas, for oil this number reaches 1017 tones which is equivalent to 231 acres of forest plantation. Figure 08 shows the comparison of different fuels.

CONCLUSION AND RECOMMENDATIONS FOR THE INDUSTRIES ACROSS PAKISTAN

The present research has focused on providing the renewable energy supply recommendations for the industrial sector of Pakistan based on the results obtained from RETscreen software. The data collected for the software is of local textile mill located in Kotri, Pakistan. Before installation of solar PV system, the mill is paying almost 20PKR/unit for HESCO supply and 10 PKR/unit for Generators supply. The on-grid solar PV system of 1 MW is proposed for the mill at initial stage. The results show that the plant will have per unit cost of 7.5 PKR. The payback period is merely 4.4 years and the NPV is almost 20 crores. This project can also reduce 732 tons of GHGs per year when compared to Natural gas fuel. The results are satisfactory and based on this research, other industries across Pakistan are encouraged to follow the same approach and shift towards renewable energies as soon as possible. Other industries across Pakistan are recommended as follows:

- The cost benefit analysis of the considered project shows that for 1 MW solar plant the payback period is under 5 years. Which will be true for most of the industries of Pakistan.
- The solar project life is up to 25 years, after first 5 years the industries can earn profits or reduce its generation costs.
- Industries either generate its power from natural gas, diesel generators or buy from discos, in both cases they pay higher costs per kWh, 20 PKR/unit average in case of HESCO supply for local mill selected for analysis. Whereas the unit can be produced in under 8 PKR by solar plant according to the results obtained.
- Global warming is a huge concern for humanity. The climate change has brought devastation recently in Pakistan in the form of flash floods. Industries are one of the major consumers of electricity, if they shift towards solar energy huge amounts of GHG can be reduced as shown in results.
- Considering the feasibility of the project other industries of Pakistan are strongly recommended to shift towards solar power and play its role for the future of Pakistani economy as well as world environment.

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