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231. Techno-Economic Analysis of Solar PV Water Pumps In Tharparkar, Pakistan

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Abstract

Developing countries like Pakistan are composed of numerous small villages and deserts, making it economically unviable to extend the electrical national grid to every location where it is needed. These countries still struggle with the lack of water in many villages and farms. These factors, along with the increase in the price of conventional energy sources and concerns regarding sustainable growth, have led to utilization of solar energy to generate the off-grid electric power is a prominent technology, which is utilized in photovoltaic based water pumping system for agriculture and community water supply in this stud. Pakistan has good sun exposure almost all year and many of its villages still have lack of water.

The target area in this research is Tharparkar desert of Pakistan. This work presents techno-economic analysis of photovoltaic based water pumping system by using mathematical model and RETScreen software.

Fuel saving per annum for selected six villages in Tharparkar has estimated as 1567 L to 5622 L.The simple and equity payback periods has estimated as 1.6 to 2.5 and 1.5 to 2.4 respectively. Annual reduction in GHG emission calculated as 3.8 to 14.9 tCO_2. Therefore, enthusiastic results have been obtained because of the occurrence and estimation of solar energy for water pumping. The results reveals that indigenous solar potential capability can be used to produce the required amounts of electrical power to meet the water drinking, non-drinking and cultivation water needs of the desert communities in environmentally sustainable manner.

Keywords: *Solar Water Pumping; Photovoltaic; mathematical model; RETScreen; Off -grid.*

1. Introduction

Humans cannot survive without energy and a certain amount of daily intake is essentially required to avoid a condition leading to starvation. To survive, a human requires at least the level of energy amounting to 5443 Joules a day, and if fewer calories are consumed, it could cause death due to starvation (Edlin and Golanty 2000). These amounts of energy are produced from food and water. The question arises as to whether the necessary amount of energy can be provided to all the areas equally, especially in the isolated places such as desert. Water is the primary source of life for humanity and one of the most basic necessities for rural development.

In developing countries, like Pakistan water pumping energy requirement is meeting out through electric and diesel power and the electric power is supplied for a limited period of the day. This duration is not sufficient for domestic, irrigation and livestock purpose, on the other hand diesel water pumping system would be used but its operation is costly because of high diesel fuel cost. Many researchers worked on the sustainable energy consumption, renewable energy sources, energy efficiency in developing countries (Akella et al 2007, Brunicki et al 2002, Elliot 2004 et al, Panwar et. al, 2011, 2013).

Solar photovoltaic (PV) water pumping has been recognized as suitable for grid-isolated rural locations in developing countries such as Pakistan .where there are high levels of solar radiation. Solar photovoltaic water pumping systems can provide water for irrigation without the need for any kind of fuel or the extensive maintenance required by diesel pumps.

The climate data on solar radiation per unit area and per unit time at Tharparkar, Pakistan on horizontal and tilted surface reveal higher values of radiation during summer months and lower in the winter months. An average solar radiation on horizontal surface is 5-7 kwh/m2/day.whrere as cleanness index 0.6 to 1(Shah, 2012).

However, in many areas of Tharparkar, water sources are spread over many miles of land and power lines are scarce. Installation of a new transmission line and a transformer to the location is often prohibitively expensive. Furthermore, diesel fuel is often expensive and not readily available in rural areas of many developing countries (Oi, 2005). The consumption of fossil fuels also has a negative environmental impact, in particular the release of carbon dioxide (CO2) into the atmosphere.

Many researchers have studied a comparative economic analysis of water pumping by different methods. Oparaku (2003) evaluated cost comparison of the photovoltaic, diesel/ gasoline generator and grid utility options to supply power in rural areas of Nigeria. Offiong (2004) assessed the economic and environmental prospects of stand-by solar powered systems in Nigeria. Schmid and Hoffmann (2004) studied economic feasibility of PV-diesel hybrid systems in Amazon for replacing diesel irrigation pumps by PV systems. In Ireland a comparison of the economic viability of photovoltaic and diesel water pumping systems is presented by Odeh et al (2005) for system sizes in the range 2.8 kWp to 15 kWp. Purohit and Purohit (2007) studied techno economic evaluation of renewable energy systems for water pumping in India Harijan. (2008) has calculated and compared the cost of water pumping through solar PV with wind and conventional pumps in Pakistan. Curtis (2010) studied the economic feasibility of solar photovoltaic irrigation system in great Basin for forage production. Mahjoubi et. al, (2010) evaluated economic viability of photovoltaic water pumping systems in the desert of Tunisia. Sako et al. (2011) studied comparative economic analysis of photovoltaic, diesel generator and grid extension in coted'ivoire. Lal .S et al (2013) studied techno economic analysis of solar photovoltaic based submersible water pumping system for rural areas of an Indian state Rajasthan.

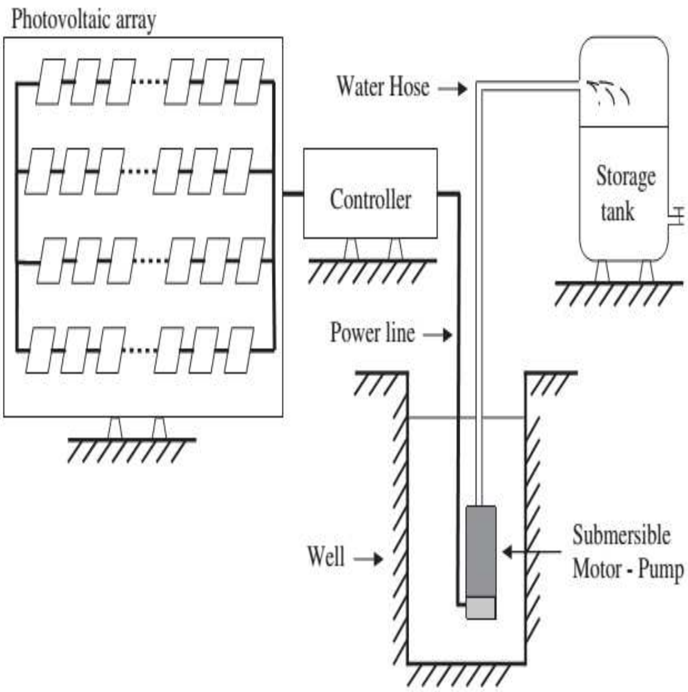

Fig. 1. Schematic diagram of solar photovoltaic water pumping

2. Analysis

The analysis has been performed by using the RETScreen Clean Energy Project Analysis (CEPA) software, which is able to perform energy production analysis, financial analysis, and GHG emission analysis.

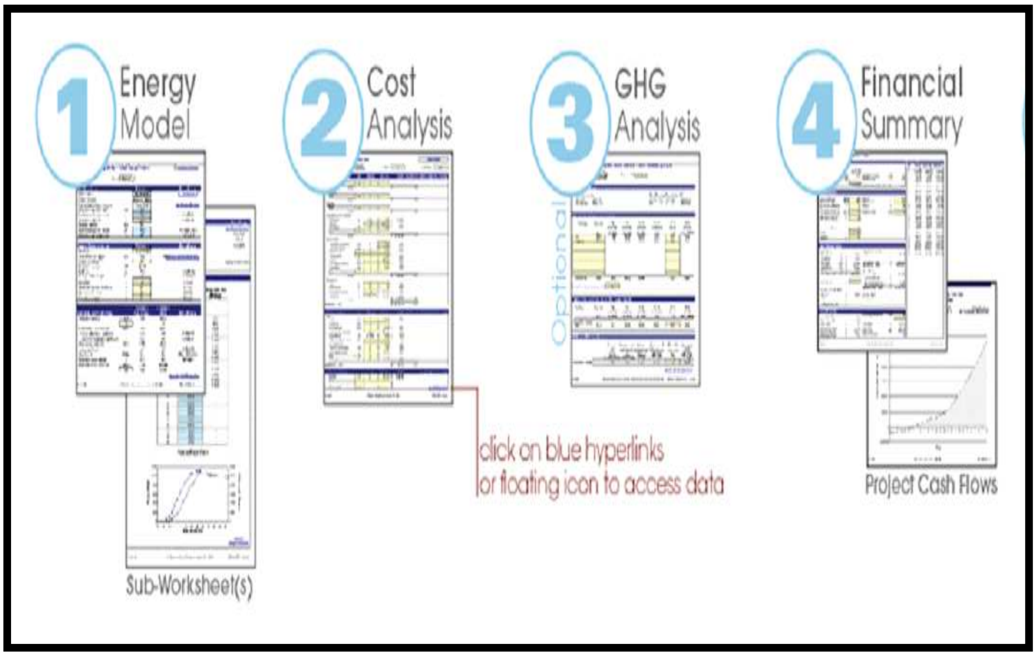

Fig. 2.1. RET Screen Model Flow diagram

2.1. Calculation of Hydraulic energy

For calculation of hydraulic energy for all selected villages in Tharparkar are carried out using mathematical equation. The basic parameter for calculation of hydraulic energy is required daily volume of water Q in (m3/d) that has to be lifted to a height h in (m) the daily hydraulic energy demand Ehydr (in J).

$$E_{hydr} = 86400\,\rho\, g\, Q\, h(1+\eta_f) \tag{2.1}$$

Where
g = acceleration of gravity (9.81 m s-2),
ρ = density of water (1000 kg m-3), and
ηf = factor accounting for friction losses in the piping.
Given the pump system efficiency pump η this hydraulic energy translates into an electrical energy requirement E pump:

$$E_{pump} = \frac{E_{hydr}}{\eta_{pump}} \tag{2.2}$$

Energy delivered is simply:

$$E_{dlvd} = \eta_{pump} \min(E_{pump}, E_A) \tag{2.3}$$

Where
EA = energy available from the array.
Daily water delivered is obtained from

$$Q_{dlvd} = \frac{E_{dlvd}}{86400\rho\ g\ h(1+\eta_f)} \tag{2.4}$$

Suggested array size is calculated simply by inverting the above equations and is therefore equal to

$$E_{pump}' / \eta_A \tag{2.5}$$

Where: ηA = overall array efficiency

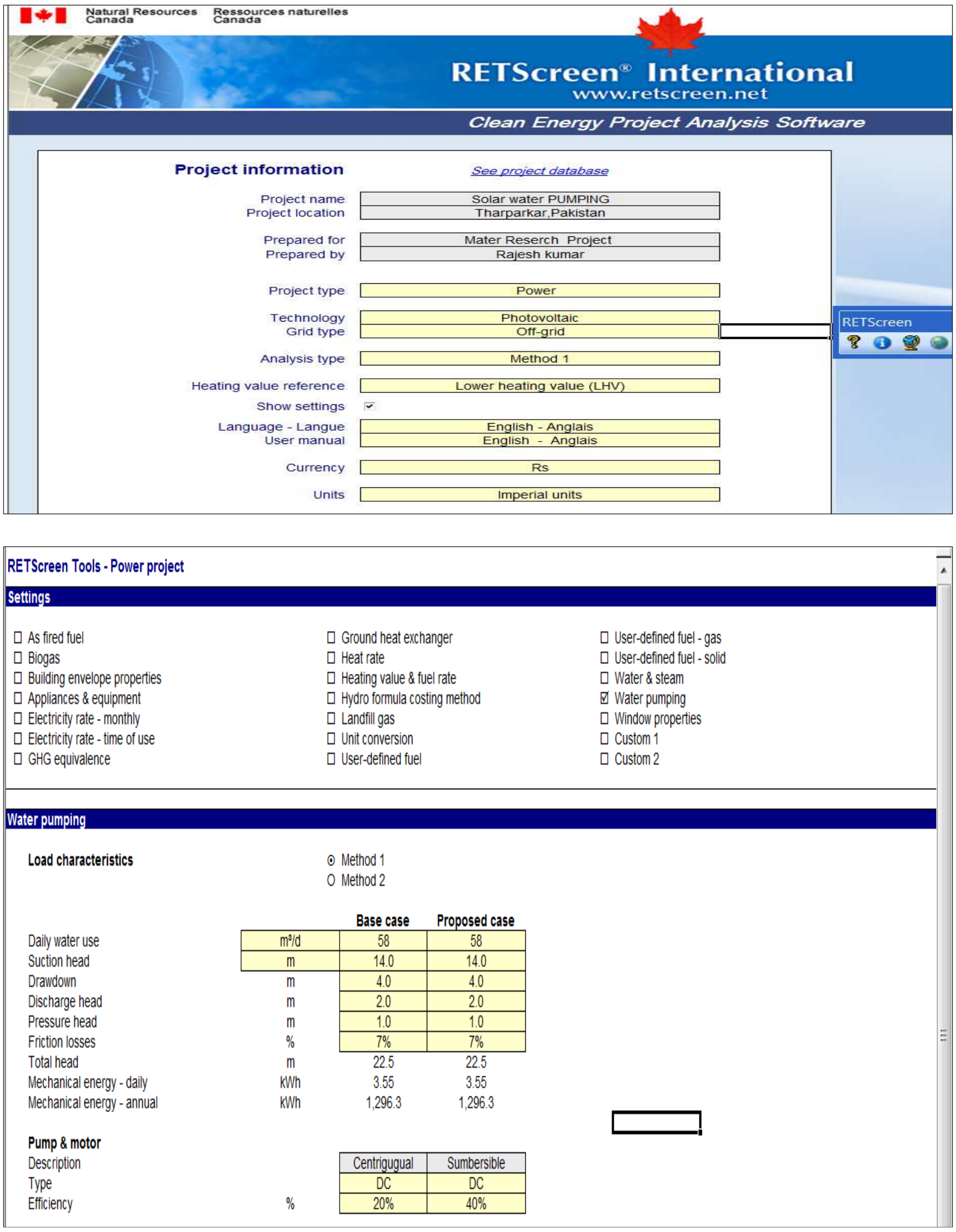

Fig. 2.2. Worksheet of Solar PV water pumping by RETScreen

Table 2. Basic Parameters for Economic Evaluation

Parameter		Unit	Value
Annual O/M cost	SPV pump	Fraction	0.01
	Diesel pump		0.10
Capital cost of the system	SPV pump (2.4 kWp)	Millions	0.55
	SPV pump (4.6. kWp)	Millions	1.0
	SPV pump (1.2 kWp)		0.35
	Diesel pump (2 kW)		0.050
	Diesel pump (4kW)		0.075
Market price of diesel		Litter	110
Overall efficiency of the diesel engine pump		Fraction	0.40
Overall efficiency of the SPV pumps		Fraction	0.40
Specific fuel consumption in diesel engine pump set		MJ/l	43.5
Useful lifetime of the SPV pump		Years	25.0
Useful lifetime of diesel engine pump		Hours	20,000
Miscellaneous losses of SPV pump		Fraction	5.0
Inflation rate		Fraction	10.8

Source: (CEPA, 2004, RETScreen2005.GOP, 2012, PSO, 2012, Lorentz 2012)

2.2. Economic analysis

Figure representing the cumulative cash flowchart for domestic and irrigation in chosen villages of Tharparkar by means of RETScreen software. In this chart simple payback period and equality payback period are illustrate. Length of the total time taken by the project is equity payback period, in situation when net cash flow results zero. Also, in the chart, the specified length of time to earn its initial cost is simple payback period. As earlier the project cost would be recovered, the investment will result more cost effective. Parallel axis is shown in years, which indicates life of project, while perpendicular axis is represented in PKR, in cumulative cash flowchart.

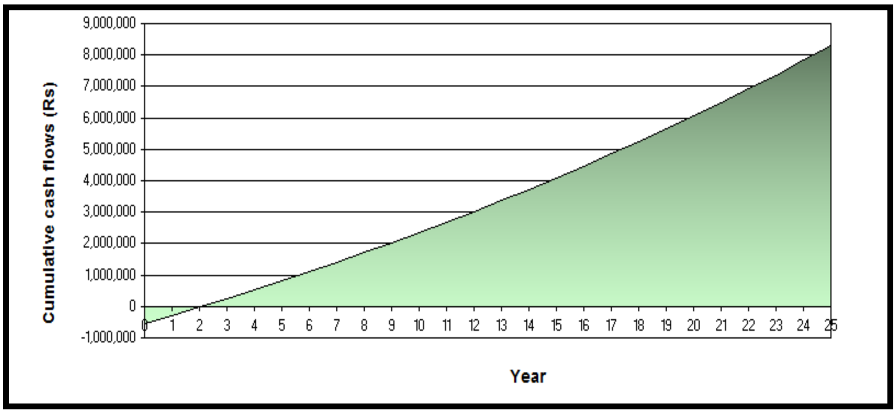

Fig. 2.3. Cumulative Cash flow Graph of Village Nabisar

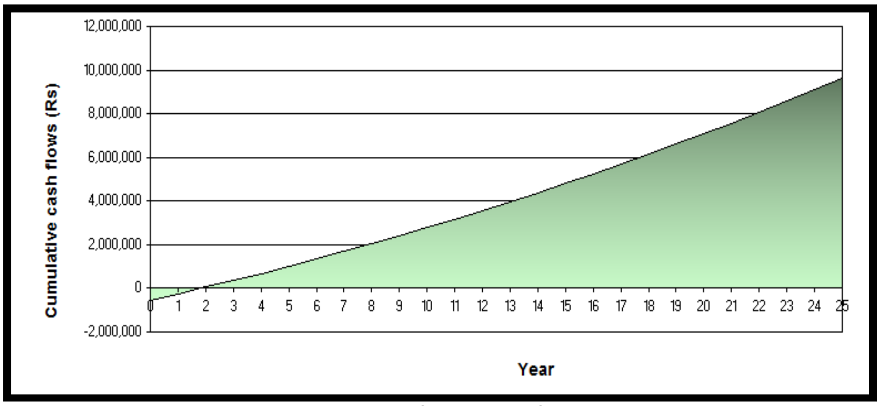

Fig. 2.4. Cumulative Cash flow Graph of Village Singharo

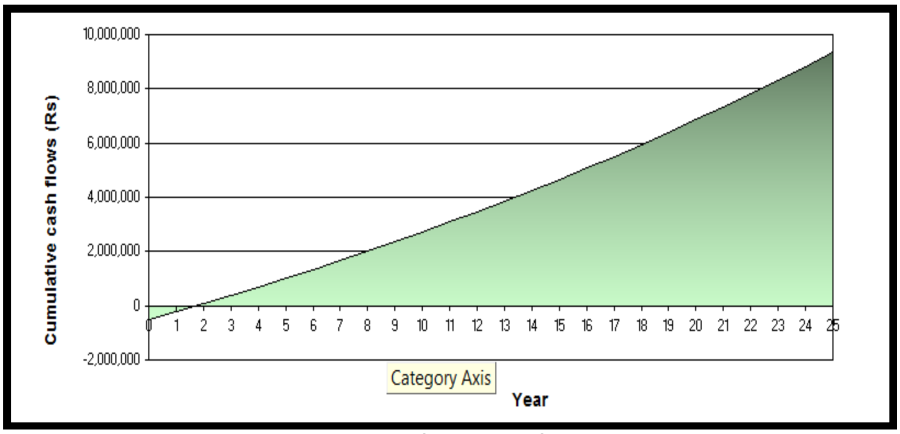

Fig. 2.5. Cumulative Cash flow Graph of Village Malo Bheel

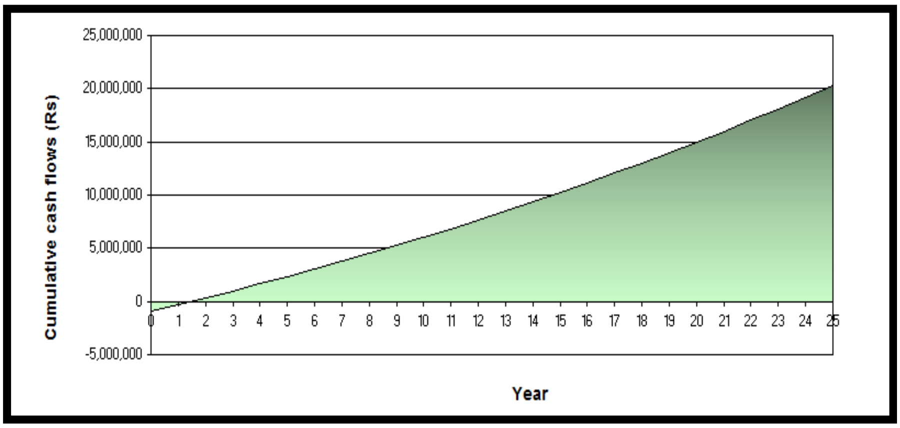

Fig. 2.6. Cumulative Cash flow Graph of Village Kasbo

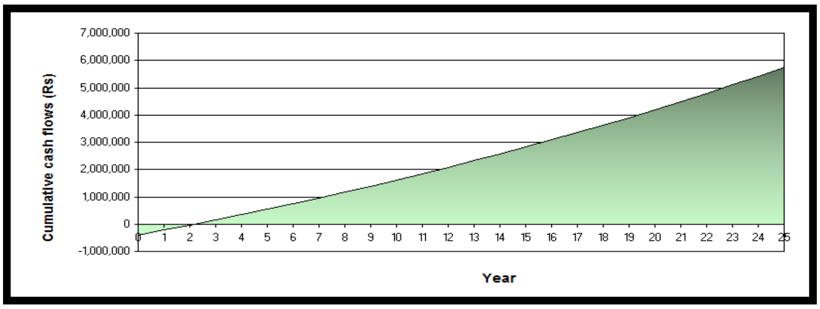

Fig. 2.7. Cumulative Cash flow Graph of Village Sarh

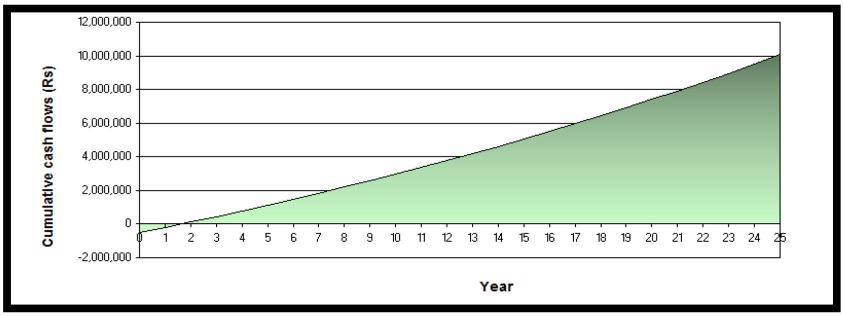

Fig. 2.8. Cumulative Cash flow Graph of Village Rarkou

3. Result and Discussions

The PV based water pumping system seems a promising option for energy conservation and it is helpful for reducing the CO2 emission. PV panels ranging from 2400Wp to 46800Wp are sufficient for domestic, irrigation and livestock's purposes for filling the water requirement in selected village of Tharparkar. Fuel saving per annum for selected six villages in Tharparkar has estimated as 1567 L to 5622 L.The simple and equity payback periods has estimated as 1.6 to 2.5 and 1.5 to 2.4 respectively. Annual reduction in GHG emission calculated as 3.8 to 14.9 tCO2. As per the environment, off Grid, fuel price and fuel import concerned with the analysis there is only PV based water pumping system can be used to produce the required amounts of electrical power to meet the water drinking, non-drinking and cultivation water needs of the desert communities in environmentally sustainable manner

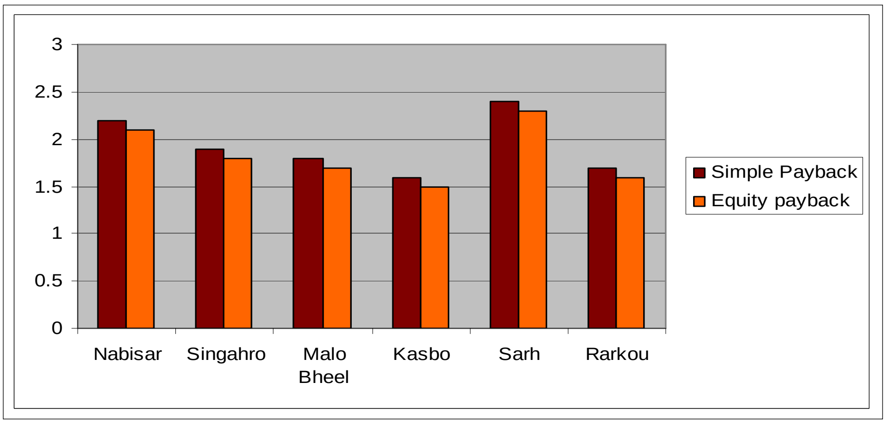

Fig.3.1: Simple & Equity Payback Period of PV pumps

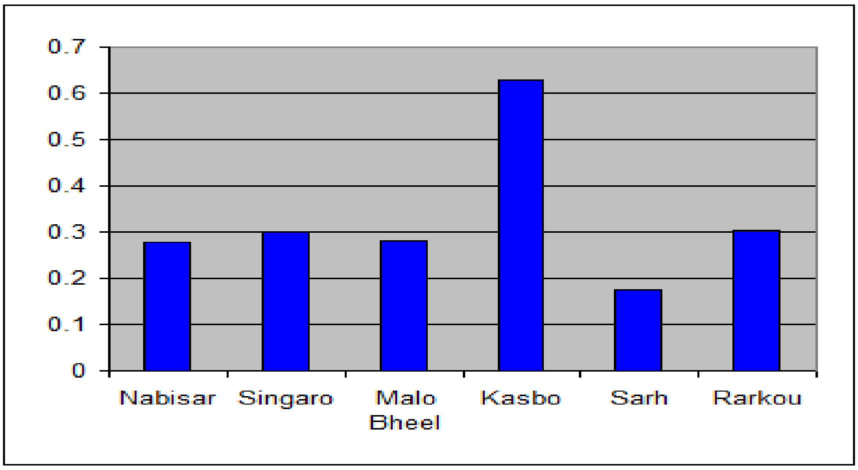

Fig.3.2: Annual Fuel Saving (PKR, Millions)

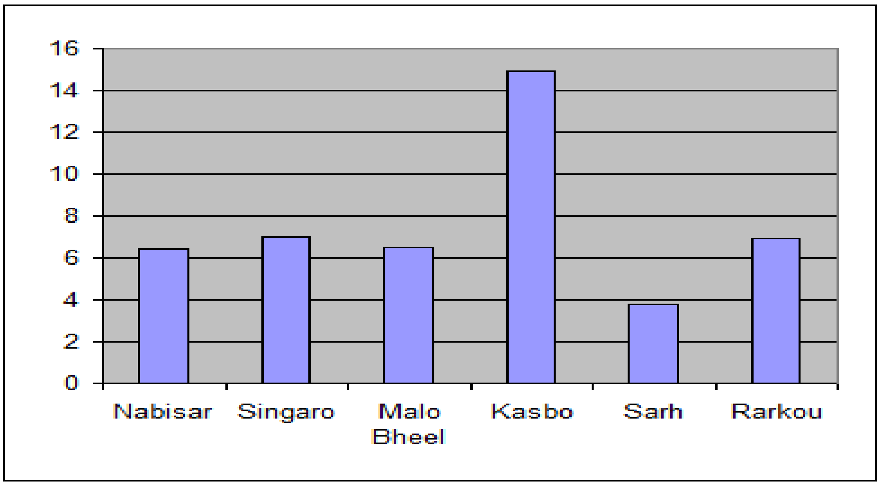

Fig. 3.3. GHG emission reduction (tCO2)

4. Conclusions

The technology is not only reduces the GHG emissions but also help in fuel conservation. The PV based water pumping system is off-grid technology means it can be utilized where grid energy is not accessible. It is economically viable option. This technology is also increasing the sustainability index. It can save money, time and environment of the world.

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