Review Article

Review of Energy Consumption and Potential of Renewable Energy in Agriculture Sector: A Case Study of Pothohar Region of Pakistan

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Abstract | Energy is a key indicator of economic development, living standards and generation of wealth of any country. Globally, energy generation scenario is shifting towards renewable sources and its application in different sectors for example Agriculture. Oil, gas and coal. The same is true for Pakistan that has agriculture based economy. The present study was undertaken to review energy consumption in the agriculture sector of Pothohar region of Pakistan. This region has no proper irrigation system due to its topography. Additionally, potential of renewable energy in Pothohar region that includes solar, wind and biogas has been calculated from the data, taken from different sources. Based on the analysis, it is estimated that the solar energy potential in Pothohar region is ~ 97321 MW, only ~ 126 MW (0.12 %) is used in Agriculture sector for different farm operations. Likewise, only 51 MW of wind energy is exploited from 63000 MW, and the potential of biogas is ~ 331, 239 m^3/day (from live stocks and poultry only). It is deduced from the data that only 0.2% of total available renewable energy is used, whereas 99.8% non-renewable energy is used in agricultural practices e.g. for the production of fertilizers (38.5%), water pumping (5.1%), farm machinery (56.2%).

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Introduction

Renewable energy sources are thought of as the solution for energy deficiencies due to the exhaustion of fossil fuel globally (Saleem et al., 2019). It is anticipated that the world energy intake will increase 28% during 2015 and 2040. The non-fossil fuel consumption is projected to grow at a quicker pace than fossil fuel. According to International Energy Agency, it has been evaluated that the world energy demand will increase from 12 billion toe to 17 billion toe by 2035 (Lefevre et al., 2013). This is due to industrialization and rapid increase in population that has also placed stringent conditions on the production of energy. Because, non-renewable energy sources are detrimental to the environment and lead to the rising sea levels, higher temperatures, droughts, rainfalls and snow storms (Burke and Stephens, 2018). Environmental impacts of greenhouse gases and depletion of non-renewable sources has forced the nations across the globe to shift their power generation to renewable sources for example Germany has planned to cut down the fossils fuel generated electricity by 2050 to ~ 20% and India has set a goal to achieve 40% of electricity generation from renewable sources (Report, 2013; MWI, 2016).

In the same spirit Pakistan has focused on generating electricity from renewable sources where Solar Park of 400 MW is functional is one such example. In Pakistan electricity generation is around 26 GW and installed capacity of electricity generation is about 36 GW, as shown in Figure 1, (NEPRA,2019).

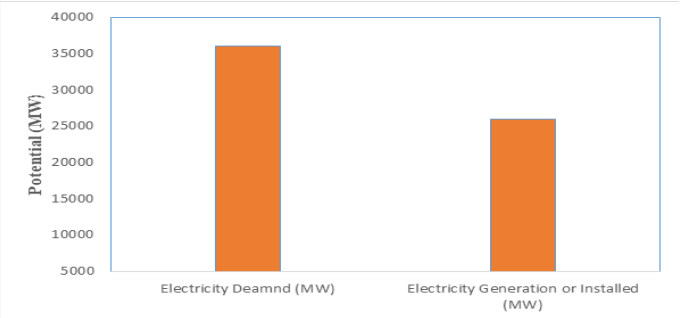

Figure 1: *Comparison between electricity demand and generation in Pakistan.*

Overall energy use in Pakistan has increased by 40% between 2000 and 2014 (IRENA, 2019). In per capita terms however, Pakistan's energy use has amplified only by about 5% between 2000 and 2014 and was only about a quarter of the world average in 2014 and only about 75% of the average lower middle income country energy use (IRENA, 2019; South et al., 2019). The Government is striving to resolve the energy crisis. Some measures are being taken with no immediate avail, while more shortages emerge in an already overstretched energy system. Energy Efficiency is recognised as the least cost short to medium term development solution to addressing energy deficits. Currently only 4% renewable energy is considering for power generation in country excluding hydropower and nuclear energy. Pakistan is trying to increase the share of renewable energy to power generation up to 30% by 2030 referring to power from wind, biomass and hydro. During 2018-19 different projects related to renewable energy has been achieved e.g. five wind power projects of 247 MW capacity and two biogas projects of 58 MW capacity were accomplished. Pakistan was determined to install 20 GW of solar power by 2022 and started working on it from January 2018, Quaid-e-Azam solar park initiative was also accomplished under this target. Now Pakistan is considering to harass the wind energy near Karachi side. Still many locations are available in Pakistan for wind, solar energy exploitation.

Scenarios for Pakistan in the One Earth framework show renewable electricity shares rising to 73% and 88% in 2030 and 2050, correspondingly (Stromquist et al., 2019) For the non- Energy crunch threatens Pakistan's economy and its risky security situation, while also badly affecting the lives of everyday residents across the board (Kugelman, 2015). The shortfall of electricity in Pakistan is about 6 GW and increasing with every passing day and load shedding is the most ominous sign of the energy. Pakistan is an agricultural country where ~ 19% of its GDP is contributed by agriculture (Nodari, 2011). Out of 79.6 million-hectare, 22.1 million hectares is cultivated and 75% of the cultivated area is irrigated, rest is rain fed (barani). A case study was performed on the consumption of energy in Agriculture sector of Pothohar region and assessment of renewable energy potential therein. Landscape of Pothohar does not allow the canal system for irrigation with the exception of seasonal canals, thus depends heavily on rain. Territory of Pothohar consists of capital area Islamabad, Rawalpindi, Attock, Chakwal and Jhelum districts, with a cumulative area of ~ 22305 km^2, as illustrated in Figure 2.

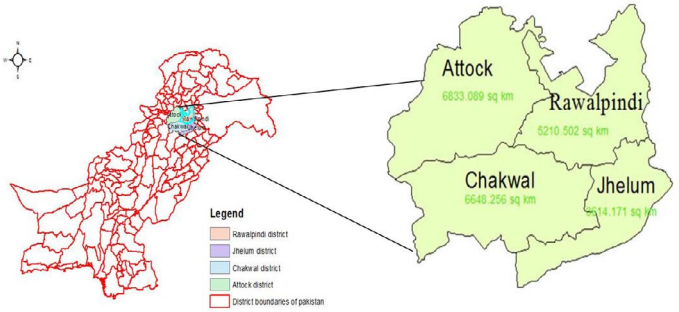

Figure 2: *Map of Pothohar Region of Pakistan.*

A district wise display of, total and cultivated area, Pothohar is shown in Figure 3. It is evident that Chakwal and Attock have more cultivated land comparatively, due to topography, favourable climatic condition and less urbanization. In Islamabad and Rawalpindi, there is no canal system for irrigation, agriculture is heavily dependent on rain, where rainwater is collected in ponds and/or ground water is pumped for irrigation. Currently, out of 25,000 acres of land, 16000 acres are irrigated by tube wells. There are small dams that are filled up by seasonal rains in Chakwal, whereas in Jhelum both tube wells and canals are the main source of irrigation. In Attock only tube wells are the main source of watering crops. Water table depth in Pothohar ranges from 200–270 ft and average rainfall is around 540–940 mm. Cultivated area is 1084 thousand hectares, whereas cropped area of Pothohar is 876 thousand hectares as

shown in Figure 3. Major crops in Pothohar are Rabi crops that include wheat, grams, maize, pea, mustard, linseed etc. and limited production of kharif crops e.g. millet, rice, groundnut etc.

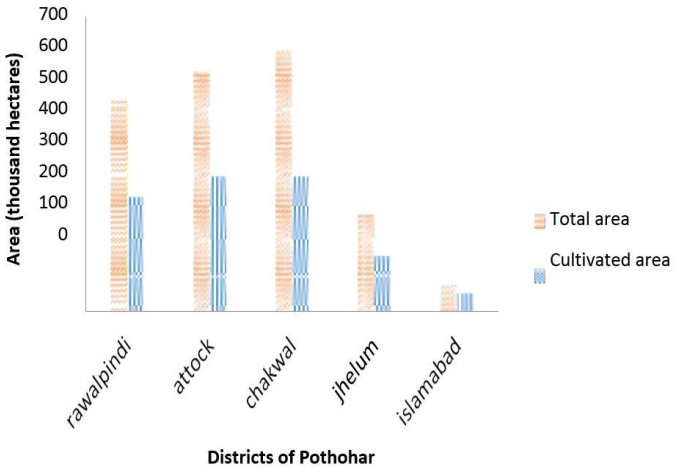

Figure 3: *Comparison between total and Cultivated area of Pothohar.*

A number of studies and reviews have been reported on subject of renewable energy potential in Pakistan and different sources of renewable energy for electricity generation. Briefly, Rauf O et al. (2015) reported that exploitable solar and wind energy resources in Pakistan are more than 50,000 MW and 20,000 MW, respectively (Rauf et al., 2015). Amjid et al. (2011) estimated the potential of biogas in Pakistan that is ~ 16.3 million m^3/day, with 21 million tons of bio fertilizer/year, sugarcane industry can generate 3000 MW (Amjid et al., 2011). Malik and Sukhera have proposed a mechanism to manage the energy resources of Pakistan specifically natural gas (Malik and Sukhera, 2012). Uddin et al. (2016) reported that the department of Punjab has installed around 1200 biogas plants in Punjab (Uddin et al., 2016). It has been estimated that 50 biogas operated tube wells can save rupees 15.8 million that would otherwise consume 1440000 litres of diesel while running 1600 hours and 765000 tube wells on biogas could save 29 million of diesel per year. Ghafoor et al. (2016) recorded that with a collection of 72 million animals dung and 785 million poultry bird faeces could yield 14.68 million m^3/day biogas that can be employed to produce 1012 MW along with slurry. A potential of more than 1200 MW hydropower in the form of micro-hydel and 30,000 – 50,000 MW from macro hydel plants (Ghafoor et al., 2016). According to Rafique and Rehman, Pakistan has 167.7 GW potential of renewable energy that is more than enough to meet the increasing demand of energy and eight times more than the current energy demand of the country (Rafique and Rehman, 2017). The above-mentioned reports emphasized on the renewable energy potential in Pakistan and have discussed the potentials of Renewable energies including solar, wind, and biogas. Whereas, this study aims to review the consumption of energy and scope of renewable energy in Agriculture sector of Pothohar region. Relevant data was collected for solar, wind and biogas from different departments and analysis was performed for the energy consumption in different agriculture applications.

Materials and Methods

Energy consumption in agriculture sector of Pothohar

In general agriculture sector requires electrical energy for the following tasks:

- Energy consumption to operate farm machinery.
- Energy consumption in water pumping.
- Energy consumption in the production of fertilizers.

Energy consumption for above three sources has been calculated as follows:

Energy consumption by tractors: Tractors are used for variety of operations at farm level, the fuel consumption and utilization factor of tractor gives a glance on total energy consumption by tractors. In Pothohar region of Pakistan, there are 21,382 numbers of tractors and consumes on average ~ 5 litre fuel per hour per tractor (Pakistan Statistics Report, 2015; Siyal et al., 2015).

$$\text{Energy consumption (Tractors)} = nuc \quad \ldots (1)$$

Where;

n, u and c are number of tractors, utilization factor (0.09) and fuel consumption in litres/hour, respectively, where 1 litre = 11.6 kWh.

Energy consumption for water pumping: In Pothohar, diesel operated pumps are of 16 horse power (hp) and pumps operating on electrical energy are 25 hp, are commonly used in agriculture for irrigation purposes. For diesel operated pumps (16 hp) in tube wells.

$$Energy\ consumption\ (16\ hp) = nuc \quad \ldots (2)$$

Where;

n, u and c are number of tube wells, utilization factor 0.1 and fuel consumption (litres/hour), respectively. It is estimated from equation II, there are total 14,369 tube wells in Pothohar and the utilization of diesel per tube well is 0.1 (Pakistan Statistics Report, 2015; Siyal et al., 2015). On the average a diesel operated pump (16 hp) for tube wells consumes diesel @ 2 litres/hour. For electricity operated pumps (25 hp).

$$Energy\ consumption\ (25\ hp) = nuc \quad \ldots (3)$$

Where;
n, u and c are number of tube wells, utilization factor (0.1) and fuel consumption in litres/hour. In Pothohar, there are 3,715 electricity operated tube wells and their utilization factor is 0.1 and consumes 18.5 units of electrical energy / hour (Pakistan Statistics Report, 2015; Siyal et al., 2015).

Energy required for fertilizers application

$$\text{Energy consumed in fertilizers} = E \times n \quad (4)$$

Where;
E and n, represents, Energy/bag and number of bags, respectively. There are 7,20,000 number of fertilizer bags in Pothohar and energy consumed / bag is 0.086 (Siddiqi and Wescoat, 2013).

$$\text{Energy per bag} = \frac{\text{total energy (TOE) in Pakistan}}{\text{total number of bags in Pakistan}}$$

Total number of bags in Pothohar = cropped area of Pothohar × application rate

Whereas;
Total energy TOE in Pakistan is 63.1 million and application rate is 1.5 (mostly wheat, pulses and grains are grown in Pothohar).

Consumption of renewable energy in agriculture sector of Pothohar

Renewable energy in Agriculture sector of Pothohar is used to run solar pumps and tube wells only.

- Energy consumption for solar pumping
- Energy consumption to run biogas tube wells
- Total energy required for solar pumping

This estimation of energy for solar pumping is performed by standard value of discharge, head of pmps of Pothohar region of Pakistan. The numbers of solar tube well in Pothohar = 457 (Bakhtiar and Ahmed, 2017).

Discharge = Q = 10 – 15 litres/sec, Head = 20 – 30 m

$$\text{Water horse power} = \text{WHP} = \frac{Q \times H}{76}, \text{Break horse power} = \text{BHP} = \frac{\text{WHP}}{\text{efficiency}}$$

Energy requirements for biogas tube wells

There are only 25 tube wells of 16 hp which are running on biogas in Pothohar and gas utilization per tube well is 0.045 m^3 (NARC);

$$\text{Energy consumption} = npg \quad \ldots (5)$$

Where;
n, p and g are number of biogas operated tube wells, power of tube well and gas consumption of tube well, respectively. Where 1m^3 = 2.1 kWh.

Potential of solar energy

Potential of solar energy in Pakistan is 2.9 million MW and in Potohar region it is 97, 312 MW. Annual direct solar radiation in Pakistan is ~ 3.3 – 6.65 kWh/m^2/day and annual direct solar radiation in Pothohar is 5.1 – 5.4 kWh/m^2/day. Total potential of solar energy and its installation in Pothohar region is shown in Figure 4.

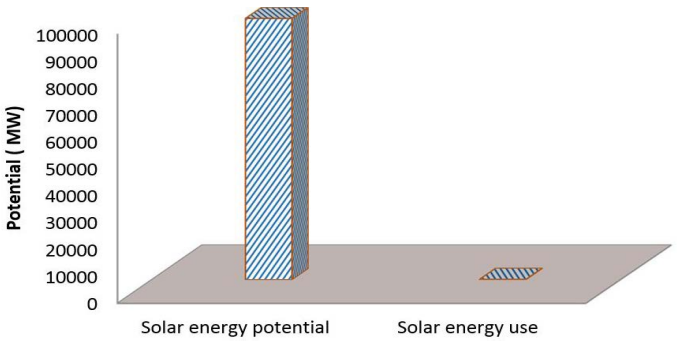

Figure 4: *Comparison between solar energy potential and solar energy utilization.*

Potential of biogas

Total potential of biogas generation in Pakistan is about 3800 MW (NRSP, 2011). In Pakistan, there are ~ 72 million cows and buffaloes and 785 million poultry. Further, 81million ton crop residue is produced every year. This is sufficient to generate 40 million kWh of electricity i.e. equivalent to 14% of the annual electricity consumed in Pakistan. Animals produce 360 million kg dung and birds 30 million kg waste/day assuming collection efficiency of 50%. Animals waste along with crops residue (60% of total) can be used to produce 24.55 million m^3 biogas/day, sufficient to generate about 41 million KWh of electricity/day or about 13, 530 GWh/annum. One m^3 gas can produce heat equal to 1kW heater for

one and a half hour (Saghir et al., 2019). A 10-cubic meter digester uses 75 kg dung daily (obtained from 7–8 Cow heads) and supplies 8–10 m^3 gas per day which is sufficient to cook three meals for a family of five or six as shown in Table 1. Biogas potential from poultry birds and biogas potential from cattle is; 12,052m^3 + 319,187m^3 = 331,239m^3/day (from live stocks and poultry only) as shown in Tables 2 and 3.

Table 1: *Relationship between plant size and gas production.*

Plant size m^3	Daily dung requirement kg	Livestock requirement bullock/cattle	Daily water requirement litres	Gas production (m^3/day)
4	30	3.00	30	4
6	45	4.00	45	6.00
8	60	6.00	60	7.00
10	75	8.00	75	9.00

Biogas potential from cattle is much larger then biogas potential from poultry, as shown in Figures 5 and 6. Biogas is produced by the biological breakdown of organic material in the absence of oxygen. The gases methane, hydrogen and carbon monoxide can be combusted or oxidized with oxygen. The raw materials for biogas include agriculture waste, animal dung, municipal waste, plant materials, sewage, green waste etc. Compositional analysis of biogas being produced in the country exhibited the following components: methane 60 – 70%, carbon dioxide 30 – 35%, nitrogen 1%, hydrogen 0.1 – 0.5%, carbon monoxide 0.1% and traces of hydrogen sulphide, while composition of natural gas that is distributed in the country consists of; methane 90.45%, nitrogen 3.32%, oxygen 0.05%, iso-pentane 0.07%, n-butane 0.17%, iso-butane 0.16%, propane 0.8%, C^{6+} 0.04%. There are total 71 biogas plants installed in Pothohar by PCRET, as shown in Figure 7 and total biogas production in Pothohar is about 771 m^3/day by PCRET (Pakistan Meteorological Department). It is estimated that 6.1 kW = 1m^3 of biogas, but due to conversion efficiency that is 35% practically of the system, only 2.1 kWh units of electricity can be produced by 1m^3 biogas plant, a unit (kWh) of electricity costs Rs. 16. So, 1m^3 of biogas can save = 16 x 2.1= Rs 33.6. Hence, Potential of biogas in Pothohar region is 331,239 m^3/day and according to our estimation the installed capacity of biogas is around 728 m^3/day in Pothohar.

Scope of wind energy and micro hydel

In Pothohar there is no application of wind energy and micro hydel in agriculture sector up till now, a national policy is needed to break the barrier for the generation of wind energy and micro-hydel in this sector. Wind potential in Pakistan is 350,000 MW. Pothohar region has a wind potential of 60 – 66 kMW (Wakeel et al., 2016). Average wind speed in Pothohar is ~ 4.5 – 10 km/hr but the scope of generating energy from wind in Pothohar is rather low, because minimum wind speed should be ~ 14.5 km/h. Rawalpindi and Jhelum have little potential for wind turbines as shown in Figures 8 and 9. Cumulative wind turbine capacity of 51 MW is installed in Pothohar for non-agricultural applications. Figures 10 and 11 shows the total and installed capacity of renewable energy in Pothohar and Pakistan, respectively (Alternative, 2018).

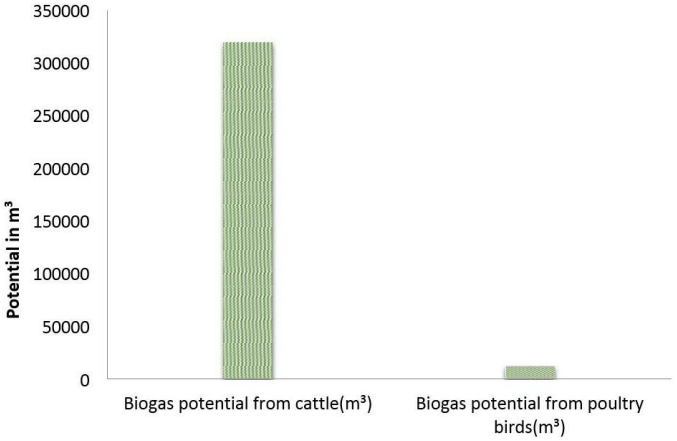

Figure 5: *Biogas potential from cattle and poultry birds in Pothohar region.*

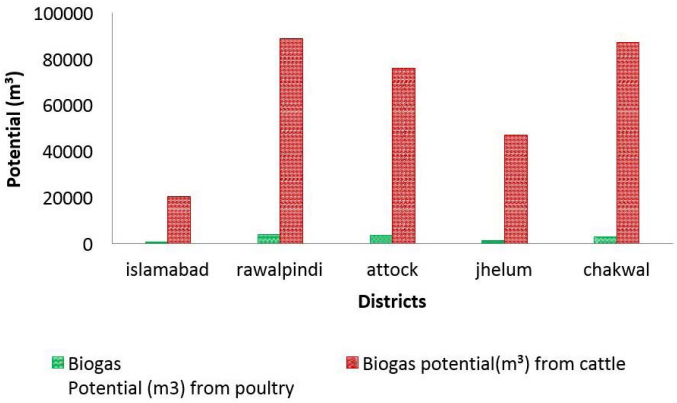

Figure 6: *Biogas potential in different districts of Pothohar.*

Based on the above discussion it is determined that total 3.364237 GWh of renewable energy is used in agriculture sector in Pothohar, where 3.033109 GWh and 0.331128 GWh is derived from solar pumping and biogas respectively. Whereas energy derived from non-renewable sources in Agriculture sector is 1,737.045271 GWh as shown in Figure 12. Table 4 displays the breakup of energy consumption in agricultural applications. Based on the data analysis,

Table 2: *Biogas and Electricity production from Buffaloes and livestock.*

Districts	Cattles	Buffaloes	Total livestock	Dung collection kg/day	50% dung collectability	Biogas potential m^3/day	Electricity Kwh/day	Pure methane m^3/day
Islamabad	51183	84424	135607	1356070	678035	20341	36308.8	12204.63
Rawalpindi	343664	247748	591412	5914120	2957060	88712	158350.6	53227.08
Attock	386192	121378	507570	5075700	2537850	76136	135901.9	45681.3
Jhelum	166781	145767	312547	5914120	2957060	46882	83684.7	28129.32
Chakwal	435276	145498	580774	587740	2903870	87116	155502.2	52269.66

Table 3: *Biogas production from poultry populations.*

Districts	Poultry population	Area (km^2)	Poultry density	waste/day @0.12kg/bird	Biogas potential m^3/day	Net caloric value MJ/m^3	Elec. kWh/d	Methane m^3/day
Islamabad	180509	8878	20.332	21661	650	13919.3586	1159.9	389.898
Rawalpindi	1065985	5285	201.7	127918	3838	82200.1068	6850	2302.524
Attock	952432	6857	138.89	114292	3429	73444.0392	6120.3	2057.256
Jhelum	329776	3587	91.936	39573	1187	25429.6098	2119.1	712.314
Chakwal	818951	6525	125.51	98274	2948	63150.8724	5262.6	1768.932

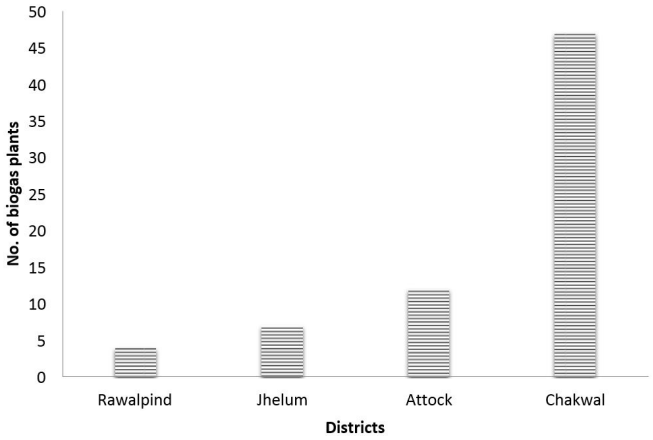

Figure 7: *Number of biogas plants.*

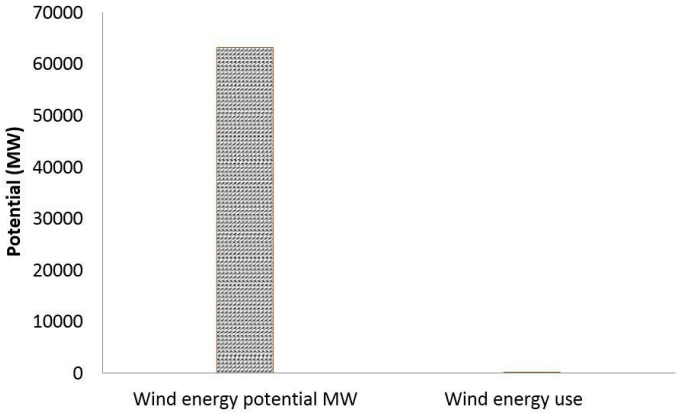

Figure 9: *Wind energy potential and utilization in Pothohar.*

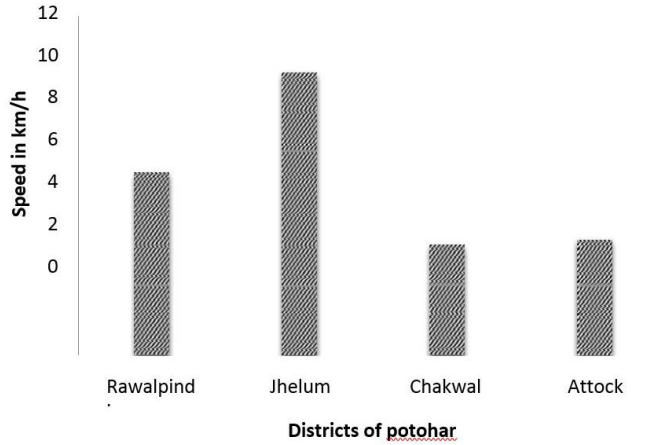

Figure 8: *Trend of wind speed in km/hr over the period of 30 years in Pothohar.*

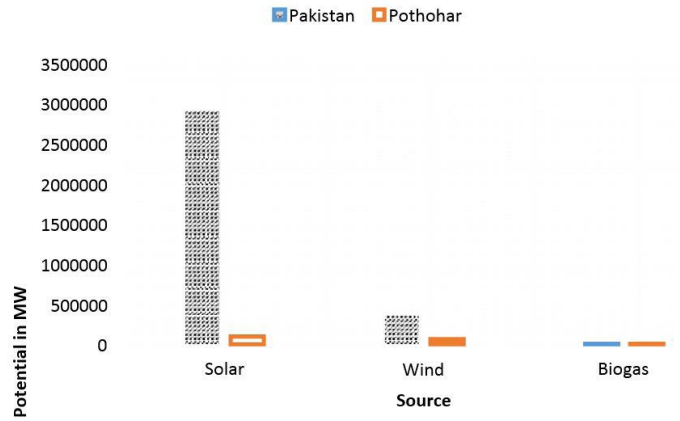

Figure 10: *Total Solar and Wind energy potential in Pakistan and Pothohar.*

Table 4: *Breakup of Energy consumption in Agriculture applications.*

Sector	Energy consumption (GWh)
Farm machinery	977.749152
Irrigation	89.4077508
fertilizers	669.888

it is estimated that only 0.2% of Renewable energy is utilized in Pothohar region of Pakistan in Agriculture sector and remaining energy (99.8%) is met from non-Renewable energy sources that is 38.5% in the production of fertilizers, 56.2% in farming (pumps etc.) and 5.1% in pumping as displayed in Figure 13.

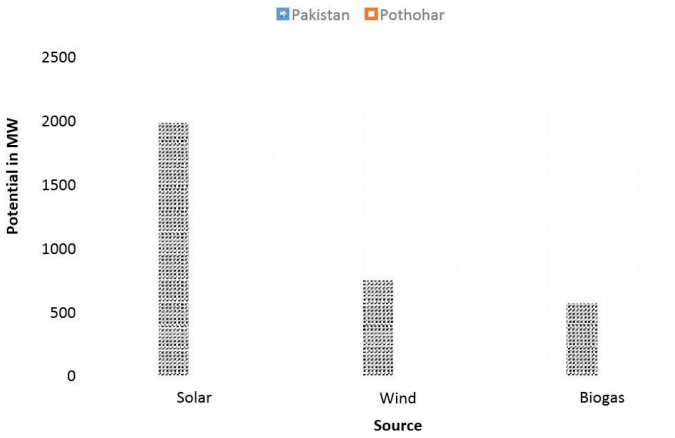

Figure 11: *Installed capacity of Solar and Wind energy in Pakistan and Pothohar.*

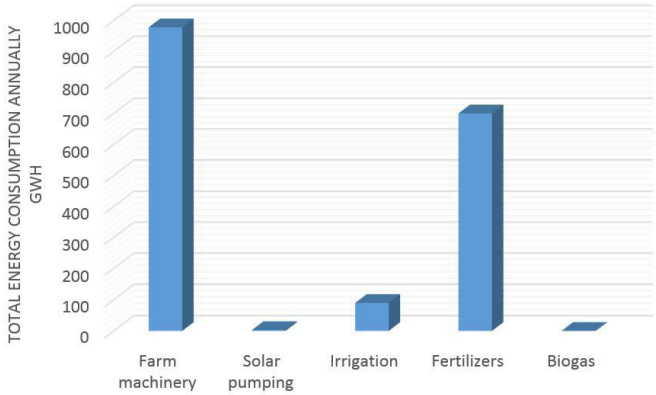

Figure 12: *Total energy consumption annually (GWh).*

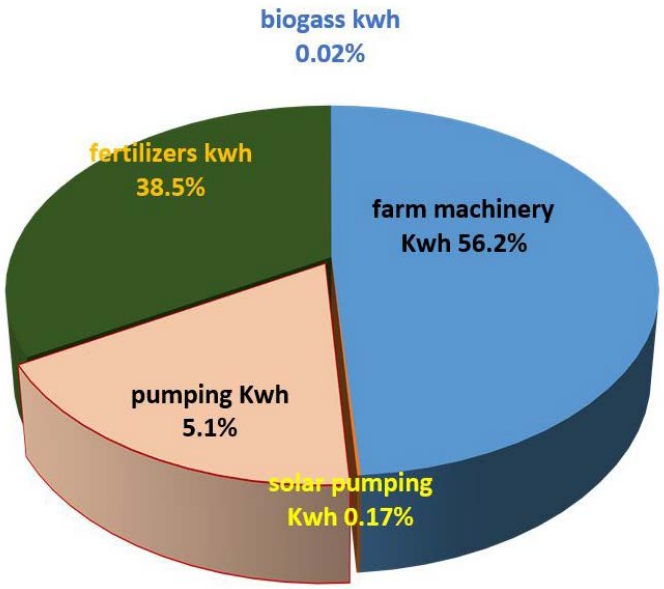

Figure 13: *Total Energy consumption in Pothohar.*

Being an agro-economy, Pakistan needs to focus on the exploitation of renewable energy sources that are abundant in Pothohar region. This shall help to save the non-renewable energy for other developmental processes and to provide economic benefits to the country. With renewable friendly policy and proper execution can help to increase the contribution of renewable energy by 15% and this would be enough to overcome the present energy gap that exists between energy potential and energy consumption. Facilitating the farming community, especially, small land owners by providing and installing the renewable energy generating equipment's that includes PV modules and wind mills, instead of loans could be an effective step.

Conclusions and Recommendations

In this study review of energy consumption in the agriculture sector of Pothohar region and potential of renewable energy is estimated for the same. As Pothohar region has no proper irrigation system like in other regions where canals are used to effectively water the crops. Landscape of Pothohar has restricted the irrigation only by rain water and/or pumping groundwater where pumps run on diesel or electricity. Pothohar region has 97,312 MW of solar and 63,000 MW of wind potential and 331,239 m^3/day of biogas (from live stocks and poultry). Only 0.12% solar energy, 0.01% wind energy and 0.22% of biogas has been utilized in Pothohar region of Pakistan. In Agriculture sector, only 0.2% of renewable energy (solar pumping, biogas) is exploited. Solar energy is utilized in different applications e.g. solar pumps, solar tube wells, Photovoltaic Modules, solar dryer, solar cooler in agriculture. Biogas is also utilized for the production of natural gas at farms and for the production of slurry which is later on used in the production fertilizers after treatment, but on a very limited scale. So, at this critical time, Pakistan needs to adopt renewable energy friendly policy and its strict implementation can not only save, in fact increases, the foreign reserve of the country.

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Author's Contribution

Filza Fatima convinced basic Idea and provided detailed research analysis, write-up and management of this paper. Muhammad Khalid Jamil refined the basic concept and Developed Research Methodology and also is corresponding Author. Dr. Muhammad

Umair has supervised research and provided technical input at different stages. Komal Qayyum; was involved in Data Collection, Data Analysis and Review of Literature. Masooma Hassan was responsible for setting References and writeup of Abstract: Syed Mohsin Raza contributed in overall formatting and write up of this paper.

Conflict of interests

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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