Solar Photovoltaic Pumpsets substitute of conventional pumpsets –A case study

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Abstract:

The growing energy demand for feeding ever increasing population has triggered the issue of energy security. This has made essential to utilize the untapped potential of renewable resources. Punjab state has great potential of generating solar energy. In the present study, the cost of running electrical and diesel tube well has been estimated along with the cost of replacement of these pump sets with solar photovoltaic (SPV) pump sets. It was found that the cost of running the electrical and diesel operated pump sets for shallow and medium tubewells, was almost Rs. 73.9 million for each year. If these pumps are replaced with the SPV pump sets, then the required cost for installation of SPV pumps is Rs 212.71 billion which is without subsidy. And as per the government scheme, the farmers share is Rs 96.18 billion and the government share is Rs. 132.71 billion. Further, with the replacements of these pump sets with solar pumping system, the green energy will be available and additional energy can be release into the grid system. This might be especially true in the state like Punjab where 30-35 % electricity is consumed in agricultural sector for irrigating about 72% area through groundwater pumping out of 99% irrigated area of the state. The cost of SPV is expected to reduce as it is gaining more and more popularity with time and with the advancement of technology, electronic goods are becoming more and more cheaper and compact.

Key words: Solar photovoltaic pumps, electrical and diesel operated pump sets, KUSUM

Introduction

Irrigation has played a major role in Punjab's agricultural growth and a substantial share of irrigation is contributed by minor irrigation schemes across the state. As stated in the 5th Minor Irrigation (MI) census reports of India, there are 11,20,963 MI schemes in Punjab, which accounts for the 5% of the total MI schemes in the country (Anonymous, 2017a). Also, Punjab is a leading state in the use of shallow tubewells, medium tubewells and deep tubewells. The number of shallow (0-35 m), medium (35-70 m) and deep

(70-150 m) tubewells in Punjab are 2,48,655, 3,84,707, 4,85,378 respectively which makes a total of 11,18,740 MI schemes in Punjab that uses ground water as the source of water (Anonymous, 2017a). Out of these 11,18,740 total MI schemes, 10,68,914 are electric pumps, 48,052 are diesel pumps, 192 wind mill pumps, 106 solar pumps and 1503 use other sources of energy for lifting groundwater.

Electricity in Punjab is generated in various plants with the burning of coal. A very large amount of electricity is used for running pumps, so a large quantity of coal is being burnt on daily basis to meet the energy demands, which further leads to a very high amount of carbon emissions in Punjab. The number of diesel pumps is also very high and therefore, a large amount of carbon emissions is coming from diesel being burnt to run pumps in Punjab on a daily basis. The oil stock of the world is being depleted at a fast pace we are all set to run out of oil over the next four decades. Coal will be exhausted in about 140 years. Switching to solar energy can help slow down the depletion coal and oil stock and further these resources will be available for use for a longer period and for critical needs when other alternatives are not viable. So, there is a need of replacing the power generated by electricity and diesel with the Solar Photovoltaic energy. Ministry of New and Renewable Energy (MNRE), Govt. of India is promoting the use of solar energy for irrigation in Agriculture sector and has launched Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme with the aim to provide energy security to the farmers, raise their income and conserve fossil fuels & environment. Government of Punjab has decided to implement the scheme in the State by providing 30% subsidy to General category farmers and 50% to scheduled caste category farmers over and above the 30% GOI subsidy under the funding pattern CS:SS:Benf = 30:30:40 and 30:50:20, respectively. The scheme is applicable in safe groundwater blocks for pumping groundwater and in dark groundwater blocks this scheme is applicable for lifting water from village ponds, tanks and canals (Anonymous, 2020a).

The earth and its atmosphere receive continuously $1.7x10^{17}$ W of radiations from the sun. The mean extraterrestrial radiation normal to the solar beam on the outer fringes of the earth's surface is called Solar constant. Average value of Solar constant is 1.366 kW per square meters

(Fröhlich and Lean, 1998). So, if a solar photovoltaic cell is installed in 1 meter square area, with 15% efficiency will produce 0.20kW of energy. If the area is 5 square meters, then it will produce about 1.0 kW of energy which is equivalent to about 1.3 horsepower and the electricity generated will be 1.0 kW-h. India has tremendous scope of generating solar energy. The reason being the geographical location and it receives solar radiation almost throughout the year, which amounts to 3000 h of sunshine. This is equal to more than 5000 trillion kWh. Almost all parts of India receive 4–7 kWh of solar radiation per sq meters (Sudhakar *et al.*, 2013)

Solar photovoltaic energy is a renewable source of energy and so the cost of applying is not much, and also the operations cost is nearly negligible, it can be considered as the most feasible, cheap and the best form of energy which can be used to run pumps. Further it will be a relief for Punjab Government as they provide full amount of electricity usage in pumps in the form of subsidy to farmers. Therefore a study is undertaken to study the potential of energy and cost saving by the replacement of diesel and electric operated irrigation pumps with Solar Photovoltaic Pumps (SPV) and the cost of replacement of electrical and diesel pump sets with Solar Photovoltaic Pumps.

Methodology:

The various data of shallow and medium tubewells was collected from various state and central agencies. The tubewell depth of 0-35 was considered as shallow and tubewell depth of 35-70 m was considered as medium (Anonymous, 2017a).

Number of tubewells according to source of energy and horsepower

There are various sources of energy being used for the operation of pumps in Punjab and horse power of these pump sets is also different. The distribution of pump set based on the energy use is given in Fig. 1 and the district wise information of shallow and medium tubewells based on their horse power is given in table 1 (Anonymous, 2017a).

The farmers are using electrical as well as diesel pump sets for irrigating their crops. The proportion of electric and diesel pump sets for determining the energy have been reported in table 2.

The crop-wise water requirement of major *kharif* and *rabi* crops of Punjab is given in table 3. The water requirement of each crop was taken from the district irrigation plan of Punjab. The crop water requirement on volume basis was determined by multiplying area and water requirement of each crop.

Estimation of energy requirements for irrigation pumping in Punjab state

District wise energy requirement for particular crop was calculated by using below mentioned formula (Patle *et al.,* 2015).

$$\mathrm{E(Kwh)} = \frac{\mathrm{V} \times \mathrm{g} \times \mathrm{h}}{3.62 \times 10^{6} \times \text{efficiency}}$$

Where, E= Energy consumption of particular crop

V =Water requirement of crop (m^3)

g=Acceleration due to gravity (9.81 m^2/sec)

h=Head (1.2H+3) (m) (Garg *et al*., 2012)

H= Water table depth, m

Efficiency= 35% (assumed)

The average water table depth of each districts of Punjab is given in table 4.

Estimation of Cost Requirements for Irrigation in Punjab State

Cost of diesel operated pumpsets

The average fuel consumption of diesel engines in Punjab is 240 grams for generating 1 kilowatt hour of energy. The density of diesel is 0.832 kilogram per litre (Ravi *et al.,* 2013). So, diesel of 240 gram weight has a volume of 0.289 litres. Therefore, the fuel consumption of diesel engine becomes 0.289 litre for generating 1 kilowatt hour of energy. So, by multiplying the values of energy consumption by diesel pumpsets in each district and each category of pumpset with 0.289 will give us the total consumption of diesel per year in each district and in each horsepower category of pumpset. The market rate of the diesel was considered as Rs. 70 per litre.

Cost of electric operated pumpsets

In Punjab, the electricity to the farmers is subsidized but as per the Punjab State Power Corporation Limited, the charges for the electricity for agricultural pump sets are Rs 5.57 per kW-h (Anonymous, 2020b).

Solar photovoltaic pump sets system rate

The total cost of solar power pump set with respect to wattage along with subsidy distribution is given in table 5.

Results:

The district-wise crop water requirement on volume basis was calculated and presented in the table 6. From the table, the highest water consuming districts are Sangrur, Ludhiana and Patiala. The highest water consumption was due to more area under paddy cultivation. The lowest water consuming districts are Pathankot, SAS Nagar and SBS Nagar because these districts are growing less water consuming crops such as maize, orchards and vegetables.

Total energy requirement for irrigating *kharif* and *rabi* crops:

The district-wise and crop wise energy requirement for irrigating the *kharif* and *rabi* crops was calculated and presented in the table 7. The highest energy requirement was for the district of Sangrur, Patiala and Ludhiana and lowest was for the Pathankot, Rupnagar and SAS Nagar. The highest energy consumption was found for the cereals followed by fodder crops and cotton. The total energy requirement for the entire districts of Punjab was calculated as about 1.2 billion kW-h. The district wise energy consumption by electrical and diesel pump sets was determined and presented in Fig. 2. The highest energy consumption through the electrical pump sets was from Sangrur, Patiala and Ludhiana and from diesel pump sets, highest energy consumption was from Bathinda. The lowest energy consumption was from Pathankot.

Operating cost of diesel and electric pump sets:

The district wise cost of diesel and electricity was determined and presented in Fig. 3. The highest energy cost was in the districts of Sangrur, Patiala and Ludhiana and the lowest energy cost

was in the districts of Pathankot, Rupnagar and Muktsar. The total cost for the running the electrical pump set was found to be Rs. 638.4 lakhs and for diesel pump sets it was Rs. 101.64 lakhs.

Cost of installing SPV pumpsets in place of electric and diesel tubewells in each district of Punjab

The cost of replacing SPV pumpsets in place of electric and diesel tubewells upto 10 hp in the category of shallow and medium tubewells in each district of Punjab with and without subsidy as per the government scheme was determined presented table …..

The cost of electrical energy and diesel for operating the shallow and medium tube wells is almost Rs. 73.9 million for each year. If these pumps are replaced with the solar photovoltaic pump sets, then the required cost of installation is Rs 2,12,711 million which is

without subsidy. And as per the government scheme, the farmers share is Rs 96,183 million and the government share is Rs 1,32,709 million. The cost of installation of SPV is very high as compared to the cost of operating electrical and diesel pump sets. But considering the possible C- emissions and degradation of environment, the replacement of theses pump sets with SPV could be viable option. During the non pumping hours, additional electricity generated through SPV can be supplied to the main grid. The district-wise cost of replacement of electrical and diesel pump sets with SPV is given in table 8.

Conclusions:

The cost of electricity is high and government provide subsidy to farmers, which makes a big burden on government of Punjab. The cost of diesel is also very much high and farmers don't get any subsidy for diesel. So it is very much difficult for them to make large profits from their crop as a large share of the profit is being spent on the diesel. A big part of carbon emission in Punjab is attributed to the electric and diesel tubewells. Therefore, it is needed to replace the electric and diesel tubewells with that of solar photovoltaic pumps. SPV pumps have only one time installation cost. The following conclusions are drawn from the study:

- The total irrigation requirement for various *kharif* and *rabi* crops of Punjab was found to be 62,014 million m^3.
- Total energy requirement for conventional method of irrigation for *kharif* and *rabi* crops is 11.94 M kW-h,
- The cost of electrical energy and diesel for operating the shallow and medium tube wells is almost Rs. 73.9 million for each year. If these pumps are replaced with the solar photovoltaic pump sets, then the required cost for installation of SPV pumps is Rs 212.71 billion which is without subsidy. And as per the government scheme, the farmers share is Rs 96.18 billion and the government share is Rs 132.71 billion.
- With the replacements of these pump sets with solar pumping system, the green energy will be available and it will help to reduce the burden on environment as electric and diesel operated pumps directly or indirectly emits carbon.

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Table 1 Distribution of shallow and medium tubewells according to horsepower (in nos.)

		No. of tubewells based on hp						
S.No.	**District**	**0-2**	**2-4**	**4-6**	**6-8**	**8-10**	**>10**	**Total**
1	Amritsar	147	165	6371	48345	203	9045	64276
2	Barnala	0	3	13	83	0	1037	1136
3	Bathinda	260	102	940	10638	1035	23206	36181
4	Faridkot	50	122	8696	3420	2783	1935	17006
5	Fatehgarh Sahib	35	63	393	3698	1	20453	24643
6	Fazilka	164	1781	11746	3929	2614	5723	25957
7	Ferozpur	28	1543	15016	8184	262	6923	31956
8	Gurdaspur	150	28840	24857	26377	3705	832	84761
9	Hoshiarpur	104	5179	8239	6123	9005	2717	31367
10	Jalandhar	41	984	5136	14233	398	30449	51241
11	Kapurthala	136	5753	6590	10765	4306	7407	34957
12	Ludhiana	110	4813	16276	16778	4052	15877	57906
13	Mansa	249	74	1140	5540	3116	18169	28288
14	Moga	1	2	18	127	0	943	1091
15	Muktsar	27	1032	24018	1823	950	756	28606
16	Pathankot	20	3053	1514	1433	2917	58	8995
17	Patiala	48	65	1182	2057	274	28486	32112
18	Rupnagar	266	2038	3115	7262	2443	4564	19688
19	Sangrur	2	2	7	396	7	3274	3688
20	SAS Nagar	38	101	1197	1053	112	1379	3880
21	SBS Nagar	39	348	3337	10926	974	3873	19497
22	Tarn Taran	28	32	533	13862	648	10983	26086
State Total		**1943**	**56095**	**140334**	**197052**	**39805**	**198089**	**633318**

(Source: Anonymous, 2017).

Table 2 Proportion of electric and diesel pumpsets (in %)

Sr. No.	District	Electric Pump	Diesel Pump
1	Amritsar	99.86	0.14
2	Barnala	100.00	0.00
3	Bathinda	83.04	16.96
4	Faridkot	96.37	3.63
5	Fatehgarh Sahib	99.72	0.28
6	Fazilka	83.90	16.10
7	Ferozpur	98.88	1.12
8	Gurdaspur	95.60	4.40
9	Hoshiarpur	84.46	15.54
10	Jalandhar	98.95	1.05
11	Kapurthala	92.48	7.52
12	Ludhiana	94.97	5.03
13	Mansa	85.64	14.36
14	Moga	100.00	0.00
15	Muktsar	98.78	1.22
16	Pathankot	59.40	40.60
17	Patiala	99.81	0.19
18	Rupnagar	72.45	27.55
19	Sangrur	99.89	0.11
20	SAS Nagar	95.75	4.25
21	SBS Nagar	94.88	5.12

Table 3 Crop water requirements of the various crops

Sr. No.	Crop	Crop Water Requirement, (mm)
1	Wheat	400
2	Rice	1400
3	Maize	400
4	Fruit Crops	800
5	Pulses	300
6	Fodder Crops	600
7	Cotton	400
8	Vegetables	500
9	Oilseeds	300
10	Sugarcane	1600
11	Others	400

(Source: Anonymous, 2017b)

Table 4 Average water table depth, m

Sr. No.	District	Water Table Depth, m	Sr. No.	District	Water Table Depth, m
1	Amritsar	14.78	12	Ludhiana	19.17
2	Barnala	29.01	13	Mansa	14.10
3	Bathinda	17.01	14	Moga	25.04
4	Faridkot	8.16	15	Muktsar	3.65
5	Fatehgarh Sahib	21.84	16	Pathankot	8.20
6	Fazilka	5.44	17	Patiala	28.05
7	Ferozpur	12.09	18	Rupnagar	13.28
8	Gurdaspur	8.67	19	Sangrur	32.10
9	Hoshiarpur	12.91	20	SAS Nagar	21.06
10	Jalandhar	22.32	21	SBS Nagar	16.96
11	Kapurthala	16.06	22	Tarn Taran	18.73

(Source: Brar *et al.*, 2016)

Table 5 SPV submersible AC pump sets rates (in Rs.)

S.N	Power HP	Total Cost	Subsidy distribution		
			Central Share (30%)	State share (30%)	Farmer share (40%)
1	3.0	1,65,558/-	49,667/-	49,666/-	66,225/-
2	5.0	2,31,305/-	69,390/-	69,390/-	92,525/-
3	7.5	3,52,500/-	1,42,705/-	1,42,705/-	1,34,180/-
4	10.0	4,39,956/-	1,00,631/-	1,00,630/-	2,38,695/-

(Source: Anonymous, 2020)

TABLE 6 District wise water requirements of *kharif* and *rabi* crops (000, m^3)

Sr. No	District	Cereals	Pulses	Cotton	Vegetables	Sugarcane	Fruit crops	Fodder crops	Other	Total
1.	Amritsar	2691400	3680	0	29900	23030	31000	29900	31000	2839910
2.	Barnala	2217090	180	0	18610	14900	650	18610	650	2270690
3.	Bathinda	2932200	22070	552970	0	0	33480	0	33480	3574200
4.	Faridkot	2154800	300	24000	0	28410	11400	0	11400	2230310
5.	Fatehgarh Sahib	1715330	70	0	38540	6230	1880	38540	1880	1802470
6.	Fazilka	2404030	0	392390	14140	5700	378700	14140	378700	3587800
7.	Ferozpur	3700530	1040	0	0	22270	710	0	710	3725260
8.	Gurdaspur	2816000	800	0	189000	30400	5140	189000	5140	3235480
9.	Hoshiarpur	1743740	870	0	213100	114600	49340	213100	49340	2384090
10.	Jalandhar	3048520	0	0	100500	163600	13160	100500	13160	3439440
11.	Kapurthala	2072770	90	0	39640	118250	3090	39640	3090	2276570
12.	Ludhiana	4614780	3600	1920	23000	51310	53840	23000	53840	4825290
13.	Mansa	1993640	460	336720	460	7580	6700	460	6700	2352720
14.	Moga	3116422	1400	4790	560	39060	9700	560	9700	3182192
15.	Muktsar	2912780	670	256000	1410	8200	13940	1410	13940	3208350
16.	Pathankot	504750	3590	0	39920	2200	32480	39920	32480	655340
17.	Patiala	4612550	1010	1680	32280	41140	18030	32280	18030	4757000
18.	Rupnagar	752860	100	0	23240	4370	2870	23240	2870	809550
19.	Sangrur	4990110	1890	39430	25950	21790	6810	25950	6810	5118740
20.	SAS Nagar	640560	2400	0	9000	36950	19240	9000	19240	736390
21.	SBS Nagar	1228900	160	0	48650	49990	10570	48650	10570	1397490
22.	Tarn Taran	3591740	5300	390	3300	930	0	3300	0	3604960
	Total	**56455502**	**49680**	**1610290**	**851200**	**790910**	**702730**	**851200**	**702730**	**62014242**

Table 7 Total energy requirement for irrigating *kharif* and *rabi* crops (kW-h)

Sr.No.	District	Cereals	Pulses	Cotton	Vegetables	Sugarcane	Fruit crops	Fodder crops	Other	Total
1	Amritsar	432001	591	0	4799	3697	4976	84373	2048	532485
2	Barnala	649159	53	0	5449	4363	190	8210	539	667963
3	Bathinda	531647	4002	100261	0	0	6070	34692	1736	678408
4	Faridkot	213421	30	2377	0	2814	1129	990	127	220888
5	Fatehgarh Sahib	387920	16	0	8716	1409	425	13843	624	412953
6	Fazilka	177306	0	28940	1043	421	27930	6007	6458	248105
7	Ferozpur	501641	141	0	0	3019	96	14864	201	519962
8	Gurdaspur	292253	83	0	19615	3155	534	13077	763	329480
9	Hoshiarpur	249666	125	0	30511	16409	7064	26062	3309	333146
10	Jalandhar	703015	0	0	23176	37728	3035	36842	0	803796
11	Kapurthala	357440	16	0	6836	20392	533	12813	2382	400412
12	Ludhiana	929145	725	387	4631	10330	10840	39326	1675	997059
13	Mansa	307489	71	51934	71	1169	1033	14613	1315	377695
14	Moga	797490	359	1226	143	9995	2482	30792	791	843278
15	Muktsar	166440	38	14628	81	469	797	6047	1002	189502
16	Pathankot	50180	357	0	3969	219	3229	2427	436	60817
17	Patiala	1309260	287	477	9163	11678	5118	35875	1885	1373743
18	Rupnagar	110382	15	0	3407	641	421	9948	371	125185
19	Sangrur	1604205	608	12676	8342	7004	2189	67060	3134	1705218
20	SAS Nagar	140219	525	0	1970	8088	4212	31167	519	186700
21	SBS Nagar	222195	28	0	8796	9038	1911	7859	4159	253986
22	Tarn Taran	649413	958	71	597	168	0	24814	540	676561
	Total	**10781885**	**8895**	**212976**	**141315**	**152205**	**84215**	**521702**	**34011**	**11937204**

Table 8 Cost of installing SPV pumps with and without subsidy (Rs, in millions)

S.No.	District	Cost without subsidy	Cost with subsidy			
			Farmers share 40%	State Govt	Central Govt	Total Govt share
1	Amritsar	22617.9	9296.5	8295.8	8295.8	16591.6
2	Barnala	489.0	260.1	117.2	117.2	234.5
3	Bathinda	14601.7	7218.3	4084.2	4084.2	8168.5
4	Faridkot	5077.8	2128.2	1691.9	1691.9	3383.8
5	Fatehgarh Sahib	10409.4	5422.0	2618.2	2618.2	5236.4
6	Fazilka	7863.2	3484.0	2421.3	2421.3	4842.6
7	Ferozpur	9756.4	4310.3	3021.9	3021.9	6043.9
8	Gurdaspur	21519.0	8506.3	7541.2	7541.3	15082.5
9	Hoshiarpur	9308.3	3807.7	3266.3	3266.4	6532.7
10	Jalandhar	19911.3	9785.0	5559.3	5559.3	11118.6
11	Kapurthala	11070.6	4803.7	3645.8	3645.8	7291.7
12	Ludhiana	18907.5	8450.5	5944.1	5944.2	11888.3
13	Mansa	11362.0	5627.5	3158.7	3158.8	6317.5
14	Moga	464.3	244.0	114.4	114.4	228.8
15	Muktsar	7040.9	2894.8	2191.0	2191.0	4382.0
16	Pathankot	2417.8	944.3	884.3	884.3	1768.6
17	Patiala	13646.4	7231.5	3286.8	3286.9	6573.7
18	Rupnagar	6530.9	2838.9	2174.8	2174.8	4349.6
19	Sangrur	1584.8	836.5	387.7	387.7	775.3
20	SAS Nagar	1317.2	607.9	395.0	395.0	790.0
21	SBS Nagar	6734.6	2862.5	2338.7	2338.7	4677.4
22	Tarn Taran	10080.0	4622.9	3215.8	3215.8	6431.7
State Total		**212711.1**	**96183.5**	**66354.7**	**66354.9**	**132709.6**

Fig. 1 Distribution of shallow and medium tubewells based on source of energy (in nos.)

Fig. 2 Energy consumption by electrical and diesel pumps (MW-h)

Fig. 3 Cost of running by electrical and diesel pumps sets

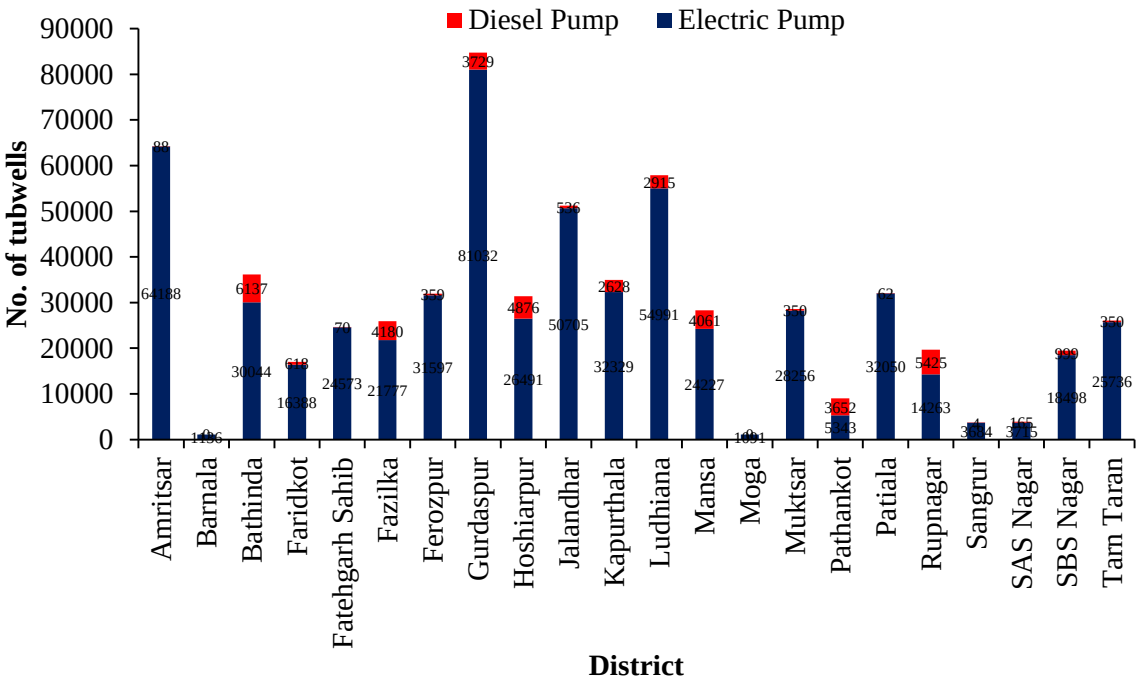

Fig. 1 Distribution of shallow and medium tubewells based on source of energy (in nos.)

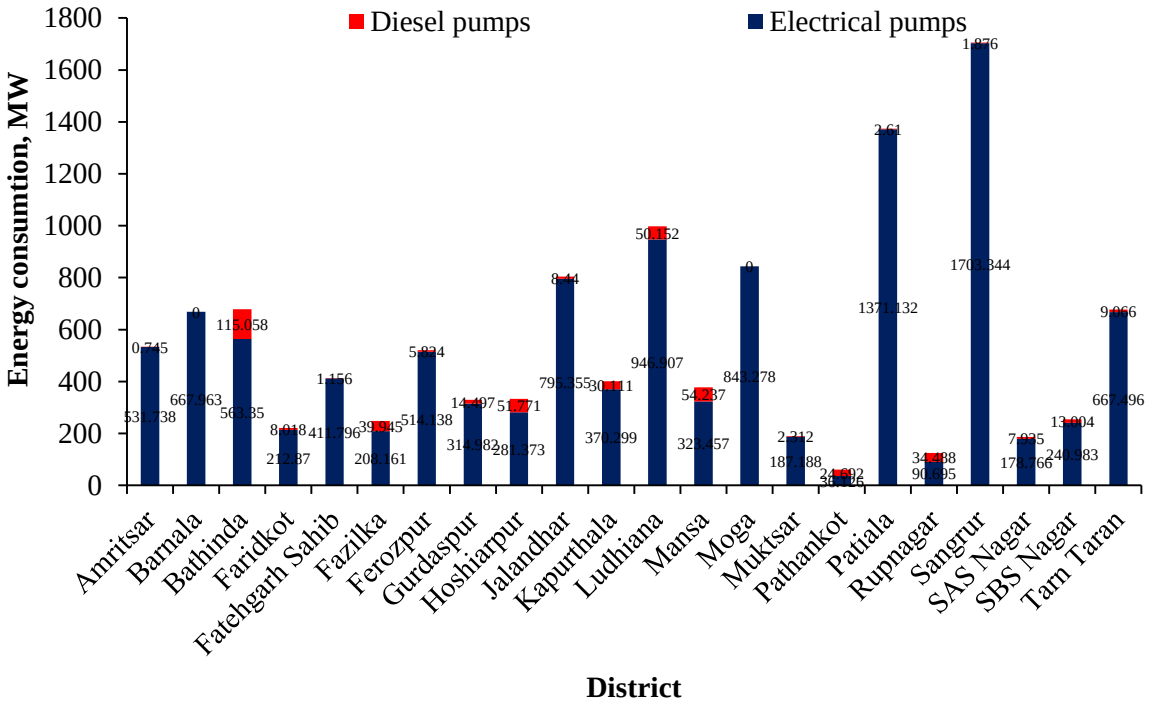

Fig. 2 Energy consumption by electrical and diesel pumps (MW-h)

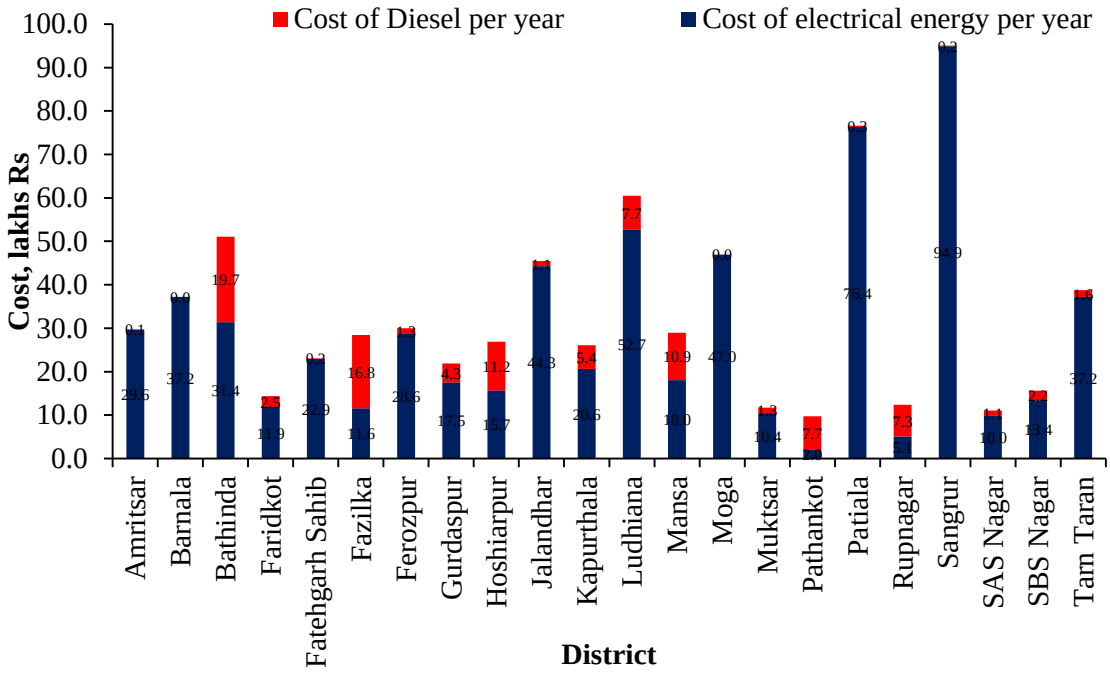

Fig. 3 Cost of running by electrical and diesel pumps sets