SAVING ENERGY IS SAVING WATER IN AGRICULTURE – A CASE STUDY OF RAJASTHAN, INDIA

[1]Mrs Nisha Payal, [2]Mr. Bhagawan Singh
[1]Associate Professor, [2]ME Scholar
[1]Mechanical Engineering Department
[1]Vivekananda Institute of Technology, Jaipur, Rajasthan, India

Abstract : The category of Agricultural consumers in Rajasthan is sub-categorized into metered and flat-rate consumers. Metered consumers are levied energy charges for actual energy consumption measured using an electronic meter, whereas flat-rate consumers are charged on the basis of sanctioned HP for the connection. The claim by Jaipur Discom, that the tariff of flat-rate consumers is kept high to incentivize them to switch over to metered category, is explored for Govindgarh block of Jaipur district in Rajasthan, India. This paper is an attempt to understand, by fifty pump set farmers from Govindgarh block, if the tariff difference is really motivating flat-rate category to become metered. A financial analysis has been done to assess the disparity in electricity bills of the two categories. The analysis suggests that it is true that flat rate consumers pay more than metered customers, but this difference is marginal if lower capacity pump sets are used. Lower is the capacity lesser is the difference. This difference, flat rate consumers can easily make up by withdrawing more water and using it for commercial purposes. Non-metering of agricultural consumers is a direct incentive to waste electrical energy as well as precious ground water resource in long term.

***IndexTerms* - Energy; water; agriculture; tariff.**

I. INTRODUCTION

Availability of water and power is positively associated with agricultural produce. Authors worldwide have applied diverse methodologies to study effect of water and power on agriculture. Stout and Fluck characterized and quantified the energy involvement of many agricultural production technologies (Stout & Fluck, 1992). In agriculture, input energy is considered in terms of human & animal labor, machinery, electricity, diesel, fertilizers and seeds. Output is in terms of agricultural produce. Input –output can be converted in terms of energy by using energy equivalent values and conversion factors. Result, as indicated by Ozkam et al., is that though output increased from 1975 to 2000 but the output–input ratio decreased from 2.23 to 1.18 from year 1975 to 2000. This may lead to associated problems such as global warming, pesticide pollution and nutrient loading (Ozkam, Handan, & Cemal, 2004). Another study based on wide range of data on input – output energy in agriculture suggests that energy input to agriculture is mainly coming from fossil fuels. (Leach, 1975) . In Iran, inputs and yield for apple production was studied. Modeling and sensitivity analysis revealed that source of maximum energy was diesel (21.88%). It was followed by manure (17.66%) and electricity (13.09%). Other inputs considered in the study were water for irrigation, chemical fertilizer and labour. (Rafiee, Avval, Mohammadi, & Ali, 2010) . In India, farm power availability has increased from about 1.6kW/ha to 3.30 kW/ha in last 50 years. Main sources of farm power are animate and mechanical & electrical. Over the years, contribution of animate power has reduced to about 14.20% whereas mechanical & electrical power has increased to about 84.80% as on now. Electrical power in agriculture is mainly needed for irrigation. (Singh, Singh, & Singh, 2010) .

A methodology in agriculture, known as Green Revolution, was started in U.S. This methodology uses chemical fertilizers, pesticides and heavy mechanization. Green Revolution is thus energy, mainly fossil fuel, intensive. This methodology , is now being used by whole of developed world. As a result, industrialized countries are heavily dependent on fossil fuels for their food production. (Pimentel, et al., 1973). Li et al. have worked on this little researched areas namely energy and water together for Shenzhen, South China. They point out that water and electricity use per GDP in agriculture was biggest among industry & construction, agriculture and residential life & services. This means that agriculture uses water and electricity most inefficiently(Li, Wen-jiang, & Lin-jun, 2013).

Sustainability of resources can be achieved if resources are used efficiently and judiciously. Researchers have critically reviewed the indicators used at policy level to measure energy efficiency of various equipments. They have discussed in detail the concept of isolating the energy efficiency trend from the aggregate indicator and how to operationalize the energy efficiency indicators. (Patterson & G., 1996). A book written by Ierland and Oude studies economics of sustainable energy in agriculture. It deals with energy efficiency, competition of land for both food production & energy crops and the economic aspects of the issues related to energy in agriculture. (Ierland & Lansink, 2002) . Natural resources scarcity is growing and food security is also a matter of concern. (Pereira, Luis Santos, Theib, & Abdelaziz, 2002) Ringler et al. studied inter- connectedness of water, land and energy resources. They suggest national governments and international bodies to promote only those investment options that co – balance the benefits of all sectors. (Ringler, Bhaduri, & Lawford, 2013)

Small affordable irrigation technologies are readily available in India and similar trends are emerging in whole of South Asia. Small private irrigation is farmer driven. It has potential for rural development and poverty alleviation (Singh, Rahman, & Sharma, 2009) At the same time, it may lead to over-abstraction, pollution, and conflicts for equitable access to water, a precious resource. (Giordano & Fraiture, 2014).

Private pumpset irrigation, already more than 58% in India, is prime method of irrigation. Agricultural consumers get subsidized electricity in this country. (Narendranath, Shankari, & Rajendra Reddy, 2005). They are sub – categorized into metered and flat rate consumers. Tariff of both the sub categories is highly subsidized compared to other categories. This results in inefficiency and over exploitation of resources.

Present study aims to assess the implications of difference in tariff among the two sub – categories, namely metered and flat rate, of agricultural consumers. It has been conducted in Rajasthan state of India. Data has been collected from 50 farmers and some government departments.

II METHODOLOGY

2.1 Location

The region selected for the study is one of the most fertile areas of Rajasthan. It lies in Govindgarh Block, North of Jaipur, the capital of Rajasthan state in India. Private micro-irrigation is very popular in this area as groundwater is only source of water for irrigation. Measurements were taken for the 50 borewell pumps to assess average operating efficiency in the field conditions. Other related data in the study such as power tariff structure of agricultural consumers, rainfall and groundwater level has been collected from Jaipur Discom (Jaipur Vidyut Vitran Nigam limited), Indian Meteorological Department and State Groundwater Board respectively.

Questionnaire

A questionnaire, as survey tool, was developed to use in this study. It contained questions related to following areas:

- Cropping pattern and ground water level
- Electricity bill
- Groundwater level and annual fluctuation
- Specifications, make, age, burnout rate, etc of the submersible pumps
- Availability of foot valve, type & size of piping, delivery valve position, etc required for estimating average operating efficiency of the pumpsets
- Rainfall

2.2 Measuring Average Operating Efficiency (AOE)

Data such as availability & working of foot valve, type & size of piping, delivery valve position, etc were collected from farmers and measurements taken for 50 pumps were used to estimate AOE of the pumps. To measure the efficiency of the pumping system, discharge, various heads and input power were measured. Tank filling method was adopted for the measurement of discharge. Total head, H, includes suction head, discharge head and friction head. Discharge side pressure gauge was used to measure the discharge head, suction head is the depth of water surface from the centre of pump and friction head was calculated on the basis of material of pipe, diameter & length of pipe. Motor input power was measured using a portable power analyzer. During actual measurements, the load was found to be unbalanced. The voltage fluctuation among the three phases was more than 1%. Two wattmeter method was used to measure the power input to the motor. In 3Ø 3W unbalanced system, values of kW1 and kW2 are measured keeping one of the wires common. Total input power,

$P_i = kW1 + kW2$

Overall operating efficiency of the system , η_{system}, is estimated as:

$\eta_{system} = (P_h)/(P_i)$.

where P_h is hydraulic power of the pump. Electric power input to the motor is denoted by P_i. it is measured using a portable power analyzer.

Hydraulic Power, P_h (kW) = $Q*H*\rho*g/1000$

Here Q is discharge in m^3/s, H is total head, ρ is density of water and g is acceleration due to gravity.

III RESULTS AND DISCUSSIONS

3.1 Existing electrical facilities

There are three distribution companies in Rajasthan which distribute electricity to the state namely, Jaipur Discom, Ajmer Discom and Jodhpur Discom. Power distribution regions of the said three Discoms are marked in the map of Rajasthan (Figure 1). Apart from Jaipur, other districts where Jaipur Discom supplies electricity are Alwar, Dausa, Bharatpur, Karauli, Dholpur, Sawai Madhopur, Tonk, Bundi, Kota, Baran and Jhalawar.

The area consisting of the said 50 pumps falls under Jaipur Discom. Consumers of Jaipur Discom are broadly categorized as Domestic, Non-domestic, Agricultural and other proposals such as Jaipur Metro Rail Corporation, etc. (JVVNL, 2014)

Figure 1: Map showing regions where Jaipur Discom distributes power

In Rajasthan, distribution system was suffering from losses to the tune of 40%. Earlier the three phase connections (mainly industrial and agriculture load) were not segregated from the single phase Domestic and Non-domestic connections. To improve upon the situation, a feeder renovation program was implemented in the area to segregate all the three phase connections (mainly industrial and agriculture load) from the single phase Domestic and Non-domestic connections. Direct insulated service line of armoured PVC cables was laid down to each agriculture consumer from distribution transformers. The 33kV substation branches to subsidiary 11kV feeders. (Figure 2)

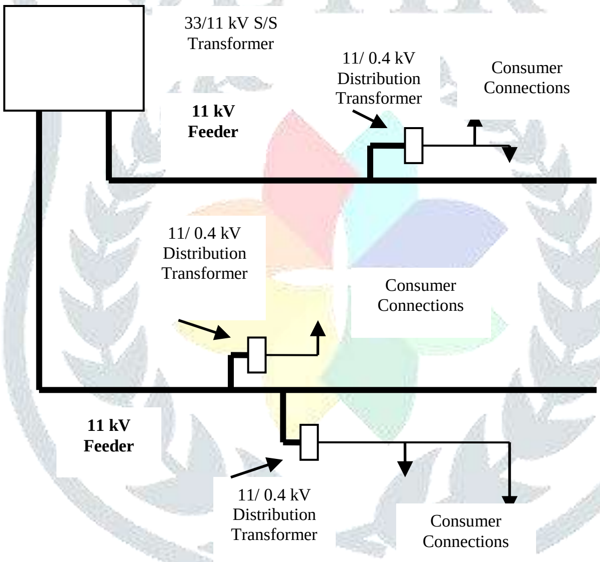

Figure 2: Distribution Structure for Agricultural consumers

The 11kV line carries power near to localities and villages. The voltage is reduced from 11kV to 415 V by a distribution transformer (DTR) at this point. These Low Tension or LT lines provide the last-mile connection to individual customers. The supply may be either single phase at 240V or as three-phase supply at 415V. As a result, distribution losses on 11 kV feeders fell to a level below 15% (Discom, 2012)

3.2 Agricultural tariff and subsidy in the area

Jaipur Discom categorises agriculture consumers as LT-4 consumers. The LT-4 agricultural consumers are further categorised into metered consumers and flat-rate consumers. Both metered and flat-rate consumers are further categorised as those who are getting supply in block hours i.e 8 hours/day and those who are getting supply more than block hours i.e. more than 8 hours/day. In the city and nearby areas, electricity is supplied more than 8 hours a day. If any agricultural connection is taken from the feeders lying in these city or nearby areas, receives power more than 8 hours a day. They are categorised as agricultural consumers getting supply more than block hours.

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Metered consumers are levied energy charges for actual energy consumption measured using an electronic meter. The tariff structure for consumers categorised as metered-consumer supply in block hours (MSBH)[1] and metered-consumer supply more than block hours (MSMBH)[2] is shown in figure 3. The tariff structure for consumers categorised as flat-rate-consumer supply in block hours (FSBH)[3] and flat-rate-consumer supply more than block hours (FSMBH)[4] is shown in figure 4.

The electricity bill has two components, namely energy charges and fixed charges. Energy charges for MSBH is Rs. 4.50/unit. State govt provides subsidy of Rs. 3.03/unit. Thus MSBH category consumers pay Rs 1.45/unit as energy charges and Rs 15/HP/month as fixed charges.

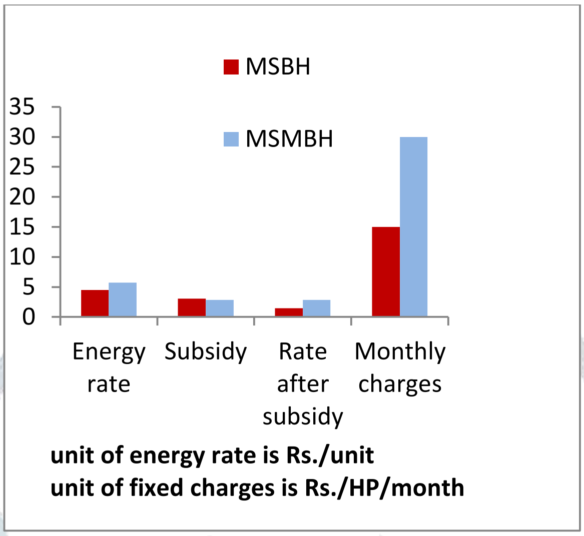

Figure 3: Tariff structure for metered agricultural consumers

The MSMBH consumers actually pay Rs. 2.85/unit as energy charges after getting subsidy of Rs. 2.85/unit on Rs 5.70/unit. Rs 30/HP/month are paid as fixed monthly charges by MSMBH consumers.

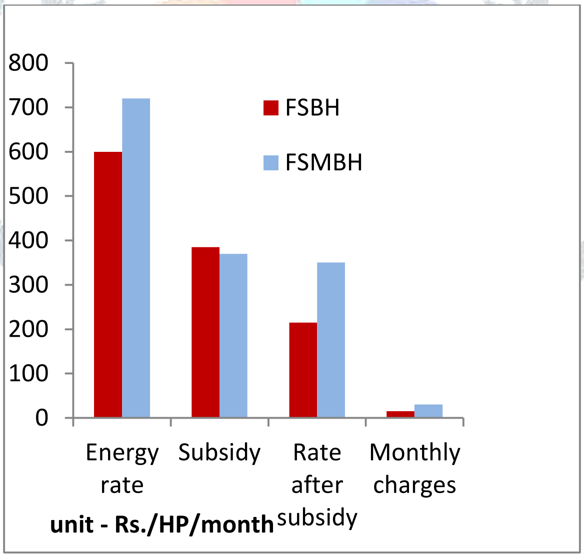

Figure 4: Tariff structure for flat-rate agricultural consumer

Flat-rate consumers are charged on the basis of sanctioned HP for the connection. In the category of flat-rate consumers, Jaipur Discom charges Rs 600/HP/month & Rs 720/HP/month as energy charges for FSBH & FSMBH respectively. State govt. then provides them subsidy of Rs 385/HP/month & Rs 370/HP/month on energy charges for FSBH & FSMBH respectively. Thus in actual, categories FSBH & FSMBH have to pay only Rs 215/HP/month & Rs 350/HP/month respectively. On and above energy charges, category FSBH pay Rs 15/HP/month & FSMBH pay Rs 30/HP/month as fixed charges (JVVNL, 2014).

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[1] MSBH:s metered-consumer supply in block hours

[2] MSMBH: metered-consumer supply more than block hours

[3] FSBH: flat-rate-consumer supply in block hours

[4] FSMBH: flat-rate-consumer supply more than block hours

It is imperative to mention here that average cost of supply for Rajasthan is Rs. 5.97/unit of electricity. (Section - IV- Tariff proposals and approved tariffs)

3.3 Cultivation and Groundwater scenario in the region

Rajasthan constituting 10.4 per cent of total geographical area, is the largest state in India. Around 5.67 % of total population of India resides in the state. About 56.5 million (65 % of population) population's livelihood is dependent on agriculture and allied activities. (GOI, 2011)

Agriculture which is the major source of livelihood of the majority in the state, is largely rainfed. Irrigation, available to around 34.5 % of total sown area, is done using surface water, canals and ground water. The said region, where survey and measurements are done, lies under irrigated area. Farmers here grow minimum two crops in a year.

The crops grown in the region can be broadly categorized under five groups namely food grain, cereals, pulses, oilseeds and others. Foodgrain comprises of wheat and rice. Cereals consists of jowar, bajra, barley, maize and millets. The pulses group consists of moong, urad, moth, chaula, gram, mater and masur. The sesame, groundnut, soyabean, castor, taramira, linseed and sunflower are together called oilseed group. Crops under category 'others' are guar, chillies, coriander, cumin, methi, turmeric, ginger, potato, onion, tobacoo, fennal, garlic and ajwain. Table 1 shows the crops under Kharif and Rabi, the two major cropping seasons of the region.

Table 1: Major crops of the region

Cropping season	Main crops cultivated in the selected area
Kharif	Maize, Bajra, Jowar, Millets, Moong, Moth, Urad, Chaula, Soyabean, Groundnut, Sesame, Moth, Moong, Gwar
Rabi	Wheat, Barley, Gram, Mater, Masur, Coriander, Cumin, Fenugreek, Potato, Onion, Garlic, Rai, Mustard, Chillies.

If the area under cultivation for the five cropping groups for the years 2006-07 and 2014-15 are plotted, a shift in cropping pattern is observed. From year 2006-07 to 2014-15, share of total food crops has dropped by 25% while the share of cereals, pulses, oilseeds and others has increased by 3%, 14%, 4% and 6% respectively. It shows shift in areas from foodgrains to other cash crops. (GOR, 2012b) , (Rajasthan, 2015), (GoR G. o., 2012a)

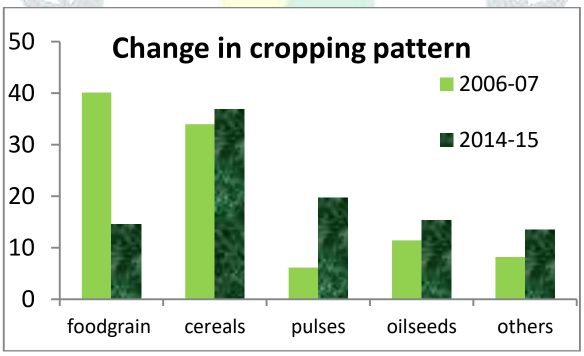

Figure 5: Shift in cropping pattern from 2006-07 to 2014-15

Though state represents India's 10.4% of total land mass, 5.5% of total population and 18.7% of total livestock, but it contains only 12% of total surface water. The rivers of the state are all rainfed except Chambal. Out of total surface water available in the state, 74% is economically utilizable. The state has harnessed 74% of its total surface water potential. (Goyal, Angchok, Stobdan, Singh, & Kumar, 2009)

Rajasthan's groundwater resources are also at an alarming state. In 1984, ground water was exploited upto a level of 35%. The level of exploitation increased to 138% by the year 2008. Out of total 237 blocks of ground water in the state, only 30 are in safe category. All others are either under overexploited category or critical category. (GoR, 2010b)

Govindgarh block annually exploits 114.954 MCM (million cubic meter) of ground water for irrigation and 10.9342 MCM for domestic & industrial uses. The annual ground water recharge for this block is only 50.6 MCM (Department of Water Resources, 2014). From 1984 to 2006 water table readied by 20.20 m in the area. Presently water is available at about 40-50m depth. The water table is falling by 0.92 m annually on an average. Many farmers have to dig new bore wells or increase the depth of existing bore well to get sufficient water every second or third year. Almost 100% of the sown area in the region is irrigated using ground water as there is no other source of water. Also all the borewells are electrified here. (Department of Water Resources, 2014)

3.4 Rain fall in the region

Rajasthan is relatively a dry state as compared to other states in the country. Average annual rainfall in the state varies from 200 to 400 mm. The region selected for study receives rainfall in the range of 500 to 700 mm which is more than the state average. The annual rainfall data of the region as provided by Department of Water Resources, Govt. of is shown in figure.

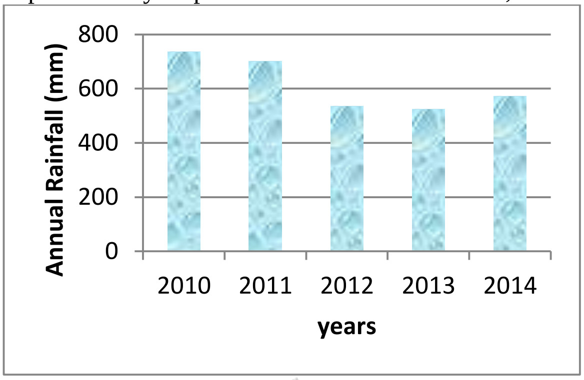

Figure 6: Last five years rainfall in the region

Annual rainfall for years 2010, 2011, 2012, 2013 and 2014 is 737, 700, 535, 525 and 572 mm respectively. Annual rainy days for the above mentioned years are 41, 36, 31, 36 and 33 respectively.
Last five years average rainfall and rainy days in this block are 614 mm and 35 respectively. Figure 6 shows variation of annual rainfall for year 2014 of Govindgarh station which falls in the region

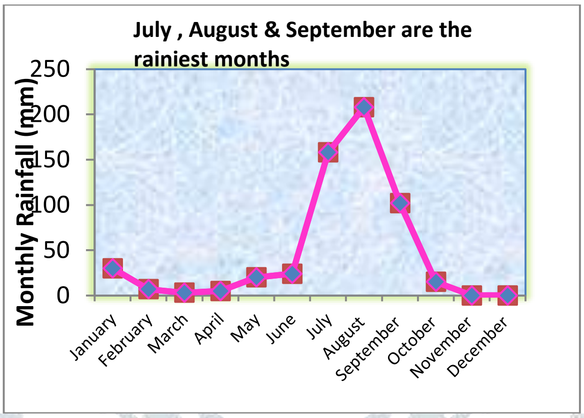

Figure 7: Annual Variation of Rainfall for Northern Jaipur (Govindgarh station)

The rainy months as can be seen in figure 6, are June, July, August and September in the region. These are months of kharif season. This is because of South – West monsoon which amounts to about 93% of total annual rainfall. July and August are the rainiest months. Only around 15% of the normal annual rainfall in the selected area is received in the months of October and November, post-monsoon period. Beyond these months, there is no rain.
Wheat is grown during November to March which is the Rabi cropping season. As can be seen from figures 6 and 7, Rabi season does not receive sufficient rainfall. So to grow Rabi crops like wheat, barley and gram, irrigation using ground water is invariably required. In fact, leave Kharif crops are also invariably irrigated in the region. As stated earlier, since there is no other source of water except ground water in the region, it is used in irrigation.

3.5 Energy Audit of pumpsets

Borewells are primary source of water in the region. Almost all the pumps are submersible pumps. The capacity of these pumps varies from 5 HP to 15 HP. Pumps of capacity 5 HP, 7.5 HP, 10HP, 12.5 HP and 15 HP are common. Maximum pump-sets are of 5 HP, 7.5 HP, 10 HP and 12.5 HP rating whereas availability of very low capacity (3 HP) and very high rating (above 20 HP) are negligible. Average operating efficiency (AOE) of the pump-sets as measured during the energy audit is summarised below in table 2.

Table 2: Average operating efficiency of the pump-sets

Sanctioned load (HP)	AOE (%)
5	26.11

7.5	26.38
10	27.04
12.5	29.48

For sanctioned load greater than 10 HP, in most of the cases, two pumps are installed. Reputed brands such as m/s CRI, Texmo, K.S.B, Varuna, Kirloskar as well as many local brands, both are available in the area. JVVNL supplies power at 3-phase, 415 V. More than 30% of these consumers are under flat-rate category. The selected feeder lines are characterized by frequent voltage variations, extremely low voltage at end of distribution line and very high loss levels. During the audit study it is observed that due to poor voltage profile motor burning rate is high in the region.

3.6 Financial Analysis

In view of Discom, tariff of flat rate agriculture consumers is higher than the tariff of agriculture metered consumers so as to incentivize them to shift to metered category. (JVVNL, 2014) As stated earlier in section 3.1, Jaipur Discom distributes power to Jaipur, Alwar, Bharatpur, Dausa, Dholpur, Tonk, Karauli, Sawai Madhopur, Bundi, Kota, Baran and Jhalawar. The area covered by these districts is not uniformly irrigated. Kota, Baran and Bundi use surface water for irrigation whereas Jaipur, Alwar and Bharatpur use ground water for the same purpose. Farmers grow two or more crops in a year here. Still lot of area is left unirrigated in these districts. In such areas, in a year, farmers thus grow single crop during Kharif season. Crop is so chosen that rainwater is sufficient for its growth. Thus though lot of variations are there in irrigation practices in these districts, electricity tariff structure is same.

A financial analysis, using collected and measured data, has been done with respect to metered and flat-rate consumers in Govindgarh block of Jaipur district. As on now, sufficient groundwater for irrigation is available in this block. Aim is to find who, metered agriculture consumer or flat-rate agriculture consumer, is paying more for same amount of water withdrawn from the ground for same duration.

Looking at the cropping pattern (section 3.3), it is assumed that all four sub-categories namely MSBH, MSMBH, FSBH and FSMBH grow Bajra during Kharif season and Wheat during Rabi in 1 hectare of land. Bajra needs around 150 mm of irrigation and Wheat needs around 500 mm of irrigation. (ICAR, 2000) Last 5 years average total rainfall during Kharif season i.e the months June, July, August and September is 507 mm (section 3.4). Thus for Bajra crop, irrigation is not required. Further, last 5 years average total rainfall during Rabi season i.e the months November, December, January, February and March is 46 mm (section 3.4). Thus for bumper Wheat crop, around 450 mm of ground water is needed. This 450 mm of ground water is withdrawn during five months of Rabi season. For rest of the months, it is assumed that metered consumers do not withdraw any amount of water. Also, most commonly used pump sets in the area are of 5 HP, 7.5 HP and 10 HP capacity. Thus, calculations for annual electricity bill, have been done separately for 5 HP, 7.5 HP and 10 HP pump-sets.

Table3: Base value of various parameters used in economic analysis

Parameter	Value
Irrigation requirement of wheat in this region of Rajasthan	500 mm
Irrigation requirement of Bajra in this region of Rajasthan	150 mm
Area of land	1 hectare
Block hour supply	8 hrs/day
Energy charges for MSBH	Rs. 1.45/unit
Fixed monthly charges for MSBH	Rs. 15/HP /month
Energy charges for FSBH	Rs 215/ HP/ month
Fixed monthly charges for FSBH	Rs. 30/HP /month
Energy charges for MSMBH	Rs. 2.85/unit
Fixed monthly charges for MSMBH	Rs. 15/HP /month
Energy charges for FSMBH	Rs 350/ HP/ month
Fixed monthly charges for FSMBH	Rs. 30/HP /month

Base values of various parameters used in the analysis are tabulated in table 3. Various pump parameters, measured during energy audit of 50 pumps, used in the analysis are tabulated in table 4.

Table 4: Pump parameters used in economic analysis

Parameters	Size of submersible pump		
	5 HP	7.5 HP	10 HP
Discharge at 60 m	140	148	200

head (lpm)			
AOE of the pump(%)	26.11	26.38	27.04

A 5 HP pump has a discharge of 140 lpm at 60m head. Its measured operating efficiency is 26.11%. When 5 HP pump is used for irrigation purpose, it has to be run for total 536 hrs to irrigate one hectare land during Rabi season. During rest of the months, it remains idle. Similarly if a 10 HP pump set is used, it has to be run for 441 hrs and in case of 10 HP pump set, number of hours are 375.

In supply in block hours category, using 5 HP pump set, a metered category consumer, MSBH, pays Rs. 11997 whereas a flat rate category consumer, FSBH, pays 15% higher Rs. 13800 as annual electricity charges. In same category those using 7.5 HP pump set, MSBH pays Rs. 14918 and a FSBH pays Rs. 20700 as annual electricity charges. It is 39% higher for flat rate category. Similarly those using 10 HP pump set, MSBH pays Rs. 16801 and a FSBH pays Rs. 27600 as annual electricity charges. So FSBH pays 64% higher than MSBH. All flat rate consumers are paying more as compared to the metered counterparts.

Same is the scenario, when the category of supply more than block hours is considered. For this category, those using 5 HP pump set, MSMBH pays Rs. 22711 and a FSMBH pays Rs. 22800 as annual electricity charges. FSMBH pays 0.39% more than MSMBH. If 7.5 HP pump set is used, a MSMBH pays Rs. 28018 and a FSMBH pays 22% higher Rs. 34200 as annual electricity charges. Those using 10 HP pump set, category MSMBH pays Rs. 31285 whereas category FSMBH pays Rs. 45600 which is 46% higher. (Table 5)

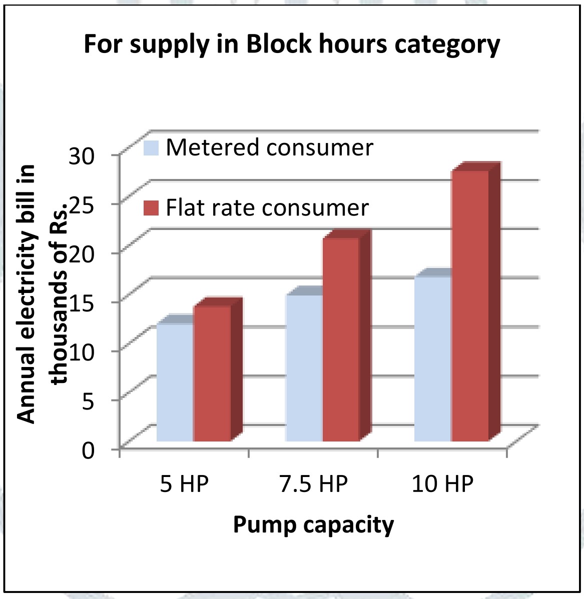

Figure 8: electricity bill of metered and flat rate consumers with supply in block hours for irrigating wheat in 1 hectare land

As noticed in earlier paragraphs of this section, flat rate consumers are paying more than metered as claimed by Jaipur Discom. This is true for both the categories namely, supply in block hours and supply more than block hours.

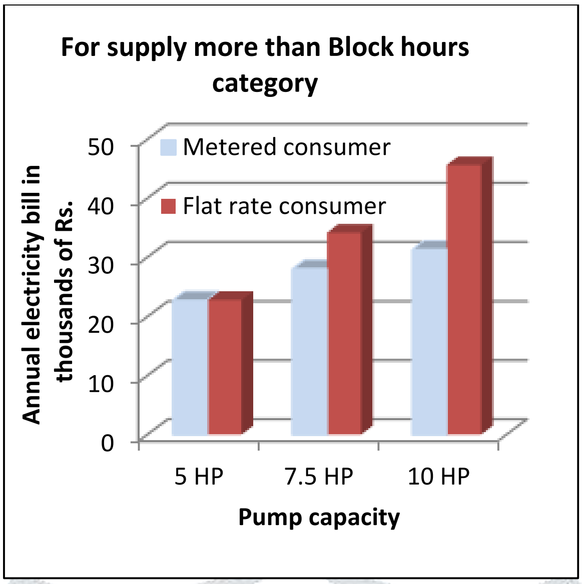

Figure 9: Electricity bill of metered and flat rate consumers with supply more than block hours for irrigating wheat in 1 hectare land

Table 5 shows the percentage by which FSBH and FSMBH are paying more than MSBH and MSMBH respectively for various capacities of pump sets. Figure 8 & 9 show the disparity in annual electricity bills in bar charts. As can be seen, the difference is marginal for 5 HP pump sets. In fact, for categories FSMBH and MSMBH, it is almost nil. As the pump capacity increases, the difference in annual electricity bill increases. No wonder, 5 HP, among all pump capacities, is most popular. Also farmers having larger areas to irrigate, take more than one connection with each having sanctioned demand of 5 HP or lower.

Table 5: Annual electricity charges for various categories using pump sets of 5 HP, 7.5 HP and 10 HP capacity

	Capacity of pump-sets		
	5 HP	**7.5 HP**	**10 HP**
MSBH (Rs.)	11997	14918	16801
FSBH (Rs.)	13800	20700	27600
% FSBH is paying more than MSBH	**15**	**39**	**64**
MSMBH (Rs.)	22711	28018	31285
FSMBH (Rs.)	22800	34200	45600
% FSMBH is paying more than MSMBH	**0.4**	**22**	**46**

Govindgarh block is near to Jaipur city, the capital of Rajasthan state. Farmers in this area grow vegetables, fruits and flowers throughout the year and supply it to Jaipur and other nearby cities. In fact, selling vegetables, fruits and flowers is financially lucrative as compared to selling crops. To say that, they are drawing water only for irrigating crops, is not entirely true. At lower capacity pump, if flat rate consumers use water for irrigation and other purposes like growing vegetables, selling water to city (which is always having shortage of drinking water), etc., he is actually saving in monetary terms. Not metering the agricultural consumers is a direct incentive to waste electrical energy as well as precious ground water resource in long term.

3.7 Conclusions

- Flat rate agricultural consumers (FSBH & FSMBH) pay more as electricity charges than metered consumers (MSBH & MSMBH) as claimed by Jaipur Discom. But this difference in annual electricity bill is marginal for lower capacity pump sets. In fact, this difference is nil between MSMBH and FSMBH.
- Since for lower capacity pump sets, difference is marginal, big farmers take more than one electricity connection with each having sanctioned demand of 5 HP or lower.
- Ground water withdrawal as small as about 85 mm by MSBH will bring them at par with FSBH in terms of annual electricity bills. It also means that if MSBH withdraw ground water little more than 85 mm, they have to pay more than FSBH.

- Flat rate farmers with lower capacity pumps, grow vegetables, fruits and flowers throughout the year and supply it to Jaipur and other nearby cities. Thus on annual basis, they draw more groundwater and pay less for the electricity as compared to metered consumers.
- For Flat rate consumers since electricity bill is fixed, they do not have any motivation in saving electricity and water. They are not interested in using energy efficient pump sets also.
- All agricultural consumers should therefore be invariably metered.

IV DISCUSSIONS AND FURTHER SCOPE OF WORK

Electricity Act 2003 was enacted aiming reforms in Indian power sector. Commercial losses and subsidy burden had plagued the sector. Major policy and regulatory changes were introduced to attract private investment to meet the growing power demand. Issues like bulk power, open access and multi – year tariff were addressed to encourage efficiency, competition and judicial use of resources (Anoop, 2006). Amongst others, one objective was to stop providing subsidy and cross subsidy to domestic and agriculture consumers. This is being done in a phased manner in the country. Presently in Jaipur Discom, cross subsidy to agriculture metered consumers is 30.7% and to flat rate consumers is 29.1%. (JVVNL, 2014).

Yet another way to altogether remove this issue of cross subsidy is to promote off-grid renewable energy technologies. Dvoskin analyses the socio-economic realities of utilizing wind, solar, effluent heat and geothermal as source of energy in agriculture. The author concluded that large scale investment and high risk are the main obstacles for large scale dissemination of renewable energy technologies (Dvoskin & Dan, 1988). The area is rich in solar energy. Average solar radiation is 5.68 (kWh/m^2/day) with more than 325 sunny days in a year. Mahmoud and Ibrik compared PV-systems, diesel generators and electric grid using computational methods. They used net present value, internal rate of return, dynamic payback period, annuity and cost annuity as economic indicators. The authors concluded that at 8% interest rate, PV-system is more economicaly feasile as compared to diesel generator and electric grid for electricfication of selected Palestine village (Mahmoud & Ibrik, 2006). Ministry of New and Renewable Energy is providing subsidy upto 40% to small and marginalized farmers to install solar powered pump-sets (Energy, 2012) . State govt may further subsidize such small private micro irrigation pump sets. (Kumar, Reddy, Adake, & Rao, 2015).

Even solar PV- diesel hybrid option for supplying power to agriculture pump sets may be considered. Solar PV- diesel hybrid option was compared with diesel power generation technology which is being used at many locations due to its low initial cost as compared to solar PV systems. Using optimization softwares, it can be shown that hybrid PV – diesel systems are less costlier from net present cost perspective(Kamel, Sami, & Carol, 2005). Commercially available softwares such as Hybrid Optimization Model for Electric Renewables (HOMER) are being used to optimize and study cost effectiveness of hybrid systems. (Razak, Juhari Ab., Kamaruzzaman, & Yusoff, 2007). Schmid and Hoffmann simulated various situations and showed that hybrid PV-diesel provide lowest cost energy source. In particular, where the transportation cost of diesel is increased by 15%, it is economical to convert a 100 kW D.G set into hybrid PV- Deisel. Where the transportation cost of diesel is increased by 45%, it is economical to convert a 50 kW D.G set into hybrid PV- Diesel. (Schmid, Aloísio Leoni, & Amaral, 2004). To handle non-linear characteristics of a PV hybrid with diesel, Dufo-Lopez and Bernal-Agustin developed a a program in C++. They called it HOGA (Hybrid Optimization with Genetic Algorithm). The authors compared the results of hybrid PV – Diesel system with stand alone PV using HOGA and another commercial program used for optimization of hybrid systems. (Dufo-Lopez, Rodolfo, & L., 2005), (Dufo-Lopez R. , 2008)

Promotion of off-grid renewable energy technologies for agriculture pump sets has a contradictory issue with ground water. With off-grid renewable energy technologies, no or very less recurring fuel cost is incurred. Owner doesn't have to pay for running the pump set. He thus tends to withdraw more ground water than required. Precious ground water, which is depleting at very fast rate, is wasted. It is ecologically unsustainable. Also, it is ruinous to farmers and economy as a whole. Carefully designed intervention strategies and policy engagements are needed to safeguard proven benefits of pump set irrigation on food security and poverty alleviation. Policies framed should consider well being of both human and environment. Efficient energy and water management are challenging tasks for the policy makers. (Fraiture, Charlotte de, & Meredith, 2014), (Levidow, Zaccaria, Maia, Vivas, Todorovic, & Alessandra, 2014)

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