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Requirement Based Evaluation of Energy Consumption in Agricultural Sector – A Case Study

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Abstract - Agriculture is primary occupation in India and largely depends on ground water because of unscheduled canals, lowrain fall etc., Electrical Energy consumption for agricultural purpose has a major share in national energy consumption. Even though several methods have been followed from the past to lift ground water, pumps operated by electrical motors occupy larger percentage. Thus availability of electricity and availability of ground water became two vital elements for flourishment of agriculture and country to prosper. Operating hours of pumpset for various crops depends on amount of water required for the crop. In a crop cycle, for proper crop growth several irrigation cycles need to be scheduled. As there is direct dependence on electricity with water required for crops, estimation of energy consumed based on water required will definitely be an imperative task of interest. There is always a chance to show a high value for energy consumed by agricultural sector, which is not metered in Andhra Pradesh. In this paper, energy consumed for various crops is estimated in six districts of Andhra Pradesh covered by Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL). This method may be useful in arriving at most reliable estimates for the energy consumed in agriculture.

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Abstract - Agriculture is primary occupation in India and largely depends on ground water because of unscheduled canals, lowrain fall etc., Electrical Energy consumption for agricultural purpose has a major share in national energy consumption. Even though several methods have been followed from the past to lift ground water, pumps operated by electrical motors occupy larger percentage. Thus availability of electricity and availability of ground water became two vital elements for flourishment of agriculture and country to prosper. Operating hours of pumpset for various crops depends on amount of water required for the crop. In a crop cycle, for proper crop growth several irrigation cycles need to be scheduled. As there is direct dependence on electricity with water required for crops, estimation of energy consumed based on water required will definitely be an imperative task of interest. There is always a chance to show a high value for energy consumed by agricultural sector, which is not metered in Andhra Pradesh. In this paper, energy consumed for various crops is estimated in six districts of Andhra Pradesh covered by Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL). This method may be useful in arriving at most reliable estimates for the energy consumed in agriculture.

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I. Introduction

Over the past two decades, ground water has emerged as one of the primary source for irrigation. Free access to power and availability of water at point of use and whenever required are leading the farmers to adapt ground water irrigation over large scale. Supply of power to agriculture has become an important and inevitable aspect.

During the past four decades, percentage of land irrigated through surface irrigation has declined and subsequently millions of small, private bore wells have come into use resulting in increased use of ground water resources and increased energy consumption. In many Indian states the consumption of 35-45% of total energy is reported in this sector and it represented not more than5-10% of state electricity board's revenue [1]. Increase in number of bore wells has put a tremendous stress on power distribution system. Though there has been an increase in number of wells, after a certain break point extraction of ground water and area irrigated with groundwater has stabilized. In Andhra Pradesh ultimate irrigation potential through ground water is 32 Million Hectares[2].

Linkage between energy and irrigation are reviewed by many authors with Government, Non-Government and social organizations in different perspectives with the aims of reduction in ground water draft, ultimate ground water potentialcomputations, water and energy nexus etc.,. S. Padmanabhan& Ashok Sarkar addressed the benefits and importance of Demand side management in India with emphasis on agricultural sector [1]. The linkage between energy consumption and agricultural ground water draft for many years with insights of India and Mexico are reviewed in [3].

Present tariff structure, poorenergy and water management appear to be responsible for high energy loss associated with the distribution network, end use of electricity in irrigation water pumping and water loss.

A careful examination of higher losses reveals that a poor cycle that exists with the involvement of two subsystems operating in tandem with one another - the electrical distribution system and the water pumping system are responsible. Because of this poor cycle, returns from this sector are very minute compared to huge investments and the utility revenues are deteriorating and subsequently fewer revenues are available for rehabilitation of distribution systems. This resulted in suboptimal planning, low quality of works and further forcing the utility to consider load shedding. Table – I describes the total energy sales and revenue from agricultural sector for various years. Table – II shows the number of pump sets used for irrigation under Category V and gross area irrigated across the state.

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Table I : Amount of power supplied and revenues in Andhra Pradesh

Year →	2008-09	2009-10	2010-11	2011-12
Total Energy sales for all DISCOMs (MU)	52,527.59	57,201.70	65037.84	70422.30
Energy Sales under category V (MU)	13,397.80	14,203.66	15197.39	16565.16
Total Revenues from tariffs (Crores)	13,510.00	15,374.33	20,939.00	25,957.91
Revenue under Category V (Crores)	142.00	129.74	74.51	147.78

Source : APTRANSCO

Table II : Number of pump sets energized and gross area irrigated

Year	No. of pumpsets energized	Gross area irrigated by Wells (Mha)	Year	No. of pumpsets energized	Gross area irrigated by Wells (Mha)
2000	19,18,712	26.93	2006	24,40,823	28.91
2001	19,24,543	26.18	2007	25,27,800	31.74
2002	19,34,389	24.78	2008	25,99,635	34.71
2003	22,49,894	25.73	2009	26,80,671	33.43
2004	23,09,605	25.63	2010	27,69,275	36.72
2005	23,74,365	27.96	2011	29,09,006	36.99[#]

Source: Agricultural research data book – 2009 & Directorate of Economics and Statistics

[#] Estimated from previous years data

The capacity of pump sets that are energized is based on the region where it is installed, crops irrigated, area of land holding. Water pumped from each pumpset is based on type of crop, depth of irrigation required, type of soil, atmospheric conditions, percolation, irrigation schedules etc. energy consumption by each pumpset is having a direct relation with amount of water pumped assuming that the water is abundantly available.Over exploitation of ground water in many regions of the state combined with idle operation of pumpsets is further leaving the entire distribution network as low efficient system.

II. Water Requirement for Crops

Regardless of the sources, water requirement (WR) of a crop is the quantity of water required in a given crop period for its maturity. WR depends on parameters like transmissivity, water retention in soil, transmission and absorption within plant, transpiration, atmospheric conditions and rain fall etc. Unavoidable irrigation losses due to Evapo transpiration, water application may need to be considered.

Irrigation requirement (IR) of a field is the sum total of irrigation need for an individual crop in a specified time plus the losses occurring in field distribution such as seepage, percolation etc. Irrigation frequency depends on crop consumptive use (CU) and the amount of available moisture in root zone. Sandy soils must be irrigated more often than fine textured deep soils. Irrigation period is the number of days that can be allowed for applying oneirrigation to a given area during the peak CU period.With the predefined water sources, main aim of irrigation scheduling is to obtain maximum production per unit water.

For the same crop, water requirement varies depending on type of soil and atmospheric conditions. In broader sense, the better classification of the areas for evaluating water requirement could be Humid, Semi Arid and Arid. As the methods of irrigation, rain fall and atmospheric conditions are not uniform across the state, region under consideration is taken as Semi Arid and crop water requirement is taken as in [5] for calculationsand the same is shown in Table III as depth of water required. In Table III Other crops include pulses, annual crops, horticulture crops, fruits and miscellaneous crops. For sesame, turmeric and chilies data is not found in the regions selected and appropriate values on higher side are considered for initiating the evaluation of net quantity of water to be applied.

Table III : Water requirement of crops in mm

Crop	Water required	Crop	Water required	Crop	Water required
Rice	1200	Turmeric	1000	Ground nuts	920
Wheat	650	Sugarcane	2700	Sesame	400
Jowar	950	Potatoes	900	Sunflower	500
Bajra	500	Sweet Potatoes	900	Soybean	680
Maize	1220	Onions	500	Tobacco	600
Ragi	450	Vegetables	750	Other crops	1250
Chilies	500	Cotton	1220		

For aiding calculations, it is considered that all the water required for crops is supplied through irrigation cycles only. Table IV shows the total area irrigated under different crops & Number of agricultural motors in six districts of APSPDCL for 2008-09, 2009-10 & 2010-11. Detailed crop wise list is available in season and crop report published by APDES.

Table IV : Area under Ground water irrigation & Number of sets Energized under APSPDCL districts [9]

Years → Districts ↓	2008-09		2009-10		2010-11	
	Area In Hectares	Number of Agricultural motors	In Hectares	Number of Agricultural motors	In Hectares	Number of Agricultural motors
Krishna	1,06,245	68,509	93,785	71,997	1,00,796	75,437
Guntur	1,04,363	60,219	1,15,284	63,226	1,28,756	66,840
Prakasam	1,12,396	92,566	1,13,941	96,408	1,26,101	1,01,645
Nellore	98,834	1,17,278	93,833	1,19,610	99,119	1,27,613
Kadapa	1,53,516	1,00,544	1,61,385	1,06,267	1,62,917	1,11,230
Chittor	1,63,117	2,38,496	1,72,123	2,49,630	1,75,612	2,62,994

Water heads for different districts for the same years is listed from the tables published by Ground water Board. Following is the list of data available in below ground water level (bgl). But in practical situations, these values cannot be considered for calculations as available heads. These values are on lower side and may not result in good estimates of power consumption.

Table V : Ground water levels in meters (bgl)

Districts → Years ↓	Krishna	Guntur	Prakasam	Nellore	Kadapa	Chittor
2009	6.85	4.75	4.92	4.27	7.23	8.4
2010	5.12	2.47	3.31	3.19	5.89	6.81
2011	4.54	2.90	3.65	3.24	5.99	6.33

III. Energy Requirement of Crops

Electrical Energy is required for crops to meet the irrigation requirement and in special cases for crop processing after the harvest. Scope of this paper is limited to evaluation of energy required for pumping water during irrigation scheduling only based on crop water requirement.

a) Estimation of Energy requirement based on actual water required

Year wise area irrigated with ground water is collected from Directorate of Economics & Statistics for listed crops and is used for calculations. Actual water required and energy required in cultivating crops is computed.

Upon knowing the actual water required in m^3, simple irrigator's equation helps in computing the time of irrigation when once the discharge is assumed.

$$A \times d = Q \times t \quad (1)$$

Where A = Area under irrigation in m^2 d= depth of irrigation in m Q= discharge through pumpset in m^3/sec t= time required for irrigation.

Discharge through pipe in lit/sec is another parameter to be assumed. It is found that high water intense crops are usually cultivated in the regions where abundant ground water is available and the discharge would be through higher diameter pipe at high velocity.

Information regarding crop wise number of irrigation resources (pumps) is not available. Hence number of irrigation pumps under each crop during estimation is worked out as percentage of water required.

Upon knowing the time of irrigation and number of irrigation resources, district wise specific energy

consumed can easily be estimated in kWh/hp. (Kilo Watt Hour / Horse Power)

$$\text{Consumption in kWh/hp} = \frac{t*0.745}{\%\text{Efficiency}} \quad (2)$$

Consumption in kWh/hp is also evaluated by modifying the number of pump sets with district wise Percentage of area irrigated in hectares. When the weighted average is taken for specific consumption based on amount of water required and area irrigated, value is found to be same. District wise results are presented from Table VI to Table VIII after estimation. Results of the proposed methodology are checked with the values given/projected by APSPDCL in Tariff Orders filings of respective years.

APDES collects district wise data every year for publishing several annual statistical reports. Data used for estimation in this paper is based on the reports from APDES and hence the estimates arevalidated.

Pump's discharge, number of pumpsets, hp ratings can be known exactly at the feeder level. It will lead to most reliable approximation with proposed calculations at micro level.

IV. Results & Discussions

As motors capacity is not known, with the help of number of motors and area under Ground water irrigation, year wise number of hectares per motor in APSPDCL districts is tabulated in Table VI.

Table VI : Year wise irrigated area: No. of hectares/ motor in APSPDCL districts

District → Year ↓	Krishna	Guntur	Prakasam	Nellore	Kadapa	Chittor
2008-2009	1.55	1.73	1.21	0.84	1.53	0.68
2009-2010	1.30	1.82	1.18	0.78	1.52	0.69
2010-2011	1.34	1.93	1.24	0.78	1.46	0.67

Table VII : District wise estimated specific consumption in kWh/hp

District → Year ↓	Krishna	Guntur	Prakasam	Nellore	Kadapa	Chittor	Average Units/hp
2008-2009	859.28	844.38	590.10	496.85	764.32	451.53	667.74
2009-2010	744.28	874.62	582.09	458.09	775.84	456.58	648.58
2010-2011	816.09	921.05	605.84	458.02	760.92	452.52	669.07

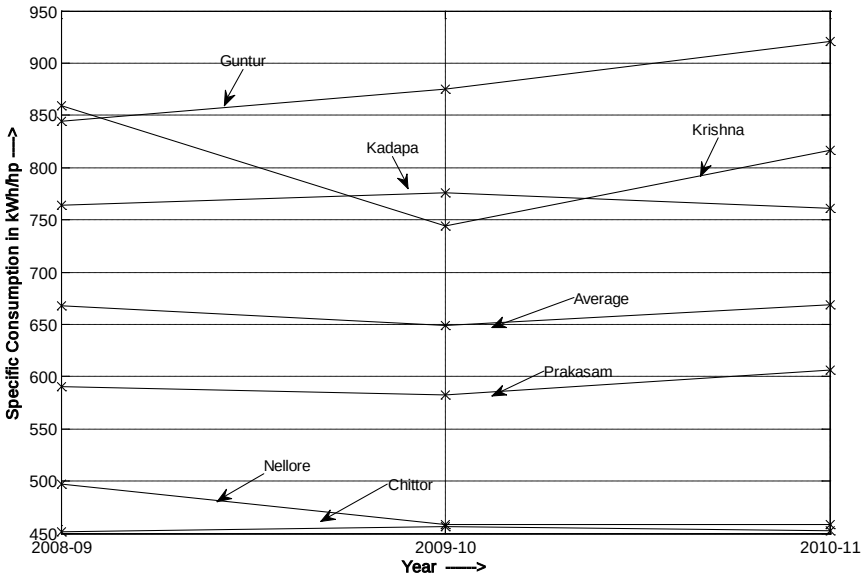

Figure 1 : Yer wise estimated specific consumption for six districts under APSPDCL

With year wise specific consumptions for all districts in Table VII,total consumption is estimated. Number of pumpsets are taken as per Table IV and district wise average hp indicated in Table VIII. District wise average hp is calculated as per the number of sets under paid category and is available in [7].

Table VIII : District wise errors in estimation with the data from APDES#[8]

Year → Districts ↓	2008-09			2009-10			2010-11		
	Agricultural Energy consumption in MU#	Estimated Consum-ption MU	%Error in Estimation MU	Agricultural Energy consumption in MU#	Estimated Consump-tion	% Error in Estimation	Agricultural Energy consumption in MU#	Estimated Consump-tion	%Error in Estimation
Krishna 4.67hp	252.20	274.92	-9.01	342.78	250.25	27.00	318.53	287.50	9.74
Guntur 4.72hp	267.19	240.00	10.18	301.00	261.01	13.29	294.23	290.58	1.24
Prakasam 5.18hp	576.56	282.95	50.92	647.00	290.70	55.07	470.83	318.99	32.25
Nellore4.28hp	449.56	249.40	44.52	523.00	234.51	55.16	560.06	250.16	55.33
Kadapa 9.01hp	989.51	692.40	30.03	1128.00	742.84	34.15	1064.70	762.58	28.38
Chittor6.17hp	1096.62	664.44	39.41	1255.00	703.23	43.97	1199.54	734.29	38.79
Total /Average 5.67hp	3631.64	2566.26	29.34	4196.78	2601.24	38.02	3907.89	2829.98	27.58

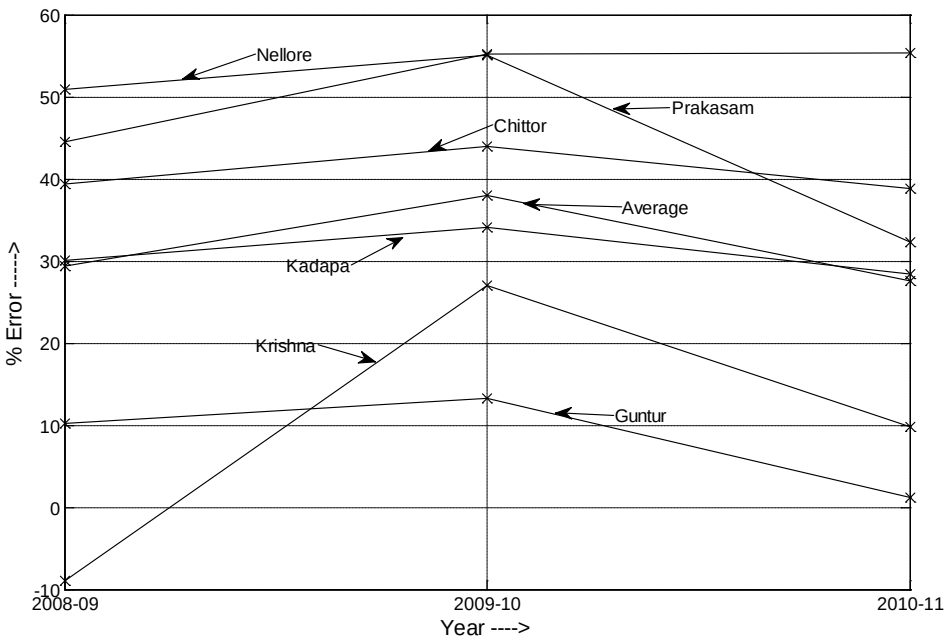

Figure 2 : Year wise % Error in estimation with data from [8]

Cumulative estimates of power consumption under all districts of APSPDCL are compared with the power consumption under agriculture category V. Total input to distribution network in MU is taken from Annual reports of respective years. Percentage of excess Consumption which may be going as losses and pilferage is calculated.

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Table IX : Estimation for the three years from values given by APSPDCL

Year →	2008-09	2009-10	2010-11
Total input to distribution network in MU	13805.48	15741.05	16449.08
Consumption Under LT Category V in MU	3459.25	4167.82	3664.49
Estimated value in MU	2566.26	2601.24	2829.98
Excess consumption in MU	892.99	1566.58	834.51
% of excess consumption reported	6.47%	9.95%	5.07%

V. Conclusions

With an aim of calculation of actual energy required to pump ground water in agricultural sector, district wise details of crops for different years are collected and the energy required is estimated. The estimation is carried out on the basis of actual water required. During computations, some parameters are assumed and the assumed values are presented. Requirement based estimation is most reliable study as it considers all the crops that are in source. To obtain results, all the water required for irrigation is assumed to be pumped through ground water only. Estimation is carried out for three years with the six districts under APSPDCL of Andhra Pradesh. District wise results are compared with the estimates published by APDES in year book s of respective years. DISCOM wise result is compared for three years with reference to consumption reported under category V. From results, Excess consumption reported by utilities can be reflected as Percentage of saving potential or amount of energy that unaccounted. Thisamount of unaccounted or loss energy would be of high value when the rain fall conditions are also taken into account. This estimation would produce most realistic value with micro level evaluation.

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