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INDIA
POWER SUPPLY TO AGRICULTURE

VOLUME 1 SUMMARY REPORT

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South Asia Regional Office

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Currency Equivalents (Annual Averages)

Currency Unit = Indian Rupee (Rs.)

1998	US$1.00	Rs.41.3
1999	US$1.00	Rs.43.1
2000	US$1.00	Rs.44.9
2001	US$1.00	Rs.48.0

FISCAL YEAR
April 1 - March 31

Abbreviations and Acronyms

APERC	Andhra Pradesh Electricity Regulatory Commission
APTRANSCO	Andhra Pradesh Transmission Company
DSM	Demand Side Management
ERR	Economic Rate of Return
FCI	Food Corporation of India
FY	Fiscal Year
GOAP	Government of Andhra Pradesh
GOH	Government of Haryana
GOI	Government of India
GSDP	Gross State Domestic Product
Ha	Hectare
HERC	Haryana Electricity Regulatory Commission
HP	Horse Power
HSEB	Haryana State Electricity Board
HVPNL	Haryana Vidyut Prasaran Nigam Limited
IPPs	Independent Power Producers
kWh	KiloWatt hours
MCM	Million Cubic Meters
MSP	Minimum Support Prices
MW	Megawatt
GWh	Giga Watt hours
PSU	Primary Sampling Unit
SSU	Secondary Sampling Unit
T&D	Transmission and Distribution

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For Haryana, officials and representatives of HVPN, HERC and Departments of Energy and Agriculture of the Government of Haryana. For Andhra Pradesh, officials and representatives of APTRANSCO, APERC, and Departments of Energy and Agriculture of the Government of Andhra Pradesh.

Acknowledgments

This report was prepared under the direction of Lucio Monari and Djamal Mostefai. It is based on several studies undertaken in collaboration with the Governments of Haryana and Andhra Pradesh and the power utilities of these states. These studies include a metering study in Haryana and farmers' surveys in Haryana and Andhra Pradesh carried out by ORG Center for Social Research. The studies were initiated in 1998 and concluded in the summer of 2000.

The concept and scope of work of the studies were discussed and agreed with Haryana and Andhra Pradesh. The sampling procedure and selection were discussed and agreed with states representatives, utilities staff, and the University of Agriculture in Haryana on the Bank team, Dr. Raheja, Dr. Bhatia and Dr. Aggarwal contributed to the development of the methodology and sampling.

We especially wish to thank Alastair McKechnie (Sector Director), Douglas French Barnes and Ashok Gulati (International Food Policy Research Institute) and the peer reviewers, Benoit Blarel, Gunnar Eskeland, Arun Sanghvi and Pedro Olinto (International Food Policy Research Institute) for their valuable guidance and support during the preparation of the study.

Preliminary results of the study and the report were discussed with officials from the Government of India and Governments of Haryana and Andhra Pradesh in several occasions 1998, 1999 and 2000 and 2001. We gratefully acknowledge the cooperation and generous help rendered by officials from the Departments of Energy and Agriculture of the Government of Haryana and Andhra Pradesh and by the Regulatory Commissions of the two states. We also wish to thank the participants of the various workshops for their comments, including Central Electricity Regulatory Commission, representatives from Governments of Rajasthan, and Uttar Pradesh, DFID, USAID, the private sector and academia.

Executive Summary

1. Throughout India, the supply of electric power falls short of the country's needs. The supply of power to Indian agriculture, vital for successful irrigation, is in particularly grave condition. Supply is neither reliable, available nor of the steady quality needed to avoid damaging the irrigation pumps it runs and severely disrupting irrigation and farming operations. The state utilities, the only source of electricity for the country's farmers are in equally bad shape. They lack the skilled personnel and management culture, for instance, to block persistent theft of power and recover the very significant revenue losses that such pilferage imposes on them. In general, they lack the financial resources to modernize their operations so that rural consumers can count on getting electricity when they need it, for as long as they need it and at voltage levels appropriate to equipment in the field.

2. None of the statements above can be a surprise to policymakers in India. The severity of the problem has long been recognized. So, too, has the theoretical possibility of raising some of the necessary finance for upgrading service and supply from rural consumers, the farmers who now pay low, heavily subsidized tariffs for electricity. The prospect of instituting such a reform, however, meets with understandable resistance from those who fear that India's farmers cannot afford the expense.

3. That anxiety exists in a vacuum of information. The impact of electricity tariffs on farming costs now and in a hypothetical future of improved service and higher charges has never been studied in detail. This report seeks to fill that void. Based on exacting studies of many aspects of farm operations in the states of Haryana and Andhra Pradesh, it finds:

- Providing highly subsidized but poor quality power to agriculture is an impediment to agricultural growth and income. Due to the erratic electric power, farmers' costs – particularly in the purchase of unnecessarily high-powered electric pumps and back-up or alternate diesel pumps and in the repair of pumps that burn out – are notably higher than they would be if supply were reliable and voltage steady. Corollary costs flow from the time lost repairing equipment and the timeliness lost in getting water to crops when it is most needed.

- Power subsidies are mistargetted as they benefits much more large farmers who use groundwater for irrigation compared to small farmers. Mirroring this, the present pricing regime based on a flat rate structure results in higher electricity prices for the small farmers compared to large farmers because of their lower level of consumption. The electricity subsidy exclusively benefits electric pump owning farmers, especially the medium to large farmers, as they predominantly own the electric pumps and account for the larger share of electricity consumption.

- The fiscal cost associated with the provision of this large subsidy is very large at 1.2-1.5 % of GSDP in Haryana and AP, creates other distortions and sacrifices elsewhere in the economy.

- Electricity consumption by farmers is estimated to be much lower than what officially attributed. This implies that theft and losses are much higher than earlier estimated. In Haryana, this results in a loss of revenue of about Rs. 7 billion per year. In other words, the state subsidies to agriculture, which are assumed to help the poor farmers, are in fact benefiting mainly better off farmers and thieves of power.

- Over the medium term, farmers' income, would increase if quality of power supply was improved partially financed through higher tariffs. Marginal and small farmers incomes stand to gain even more from an improvement in the power supply conditions at higher tariffs.

4. Two important recommendations follow from the above findings, that is the need for metering all consumers and for a communication campaign. Metering is essential for reducing theft and restore an equitable electricity pricing policy for agriculture. To achieve a broad based consensus and support for reforms, it is critical to foster an increased awareness and understanding among general public and farmers community in particular about the potential benefits of reforms, and the level of theft and pilferage.

5. Implementation of reforms remains the challenge that India faces. From the technical point of view, a possible entry point could be the implementation of an integrated approach to supply and end-use efficiency. This approach combines the improvement in the quality of power supply through a rehabilitation of the electricity distribution network with the metering installation and the replacement of existing with more efficient irrigation pumpsets to conserve energy and water which limiting the impact of tariff adjustments. New institutional and incentive systems, however, are also required to implement this program. Significant management, custom relations and marketing skills, changes in corporate culture, load research, program monitoring and evaluation skills, etc. are required, none of which is readily available in the utilities today.

6. In summary, improving the quality of electricity services to agriculture, and therefore, improving farmers' income and agriculture growth, require the in-depth power sector reforms that few Indian states have embarked upon. Farmers, notably the small and marginal farmers, will substantially benefit from these reforms.

CHAPTER 1

POWER SUPPLY TO AGRICULTURE
CASE STUDIES OF HARYANA AND ANDHRA PRADESH

A. Introduction

1.1 After almost a decade of high-level effort to bring the charges (tariffs) that farmers pay for electricity more nearly into line with the costs of supply, India has barely made a dent in the long-standing and increasingly uneconomical practice of subsidizing power to agricultural consumers for irrigation. Progress has been slowed by the understandable but misplaced concern that higher tariffs would harm farmers – and that the injured parties would take political revenge on the reformers. This study seeks to dispel that anxiety. It is the result of a joint effort by the Bank and the states of Haryana and Andhra Pradesh, both of which have begun raising the price of electricity to agriculture. Its central contribution to policy discussion is the detail in which it documents the costs – usually neither acknowledged nor clearly defined -- to farmers in those states of subsidies that actually harm agricultural operations more than they help as well as the benefits that the farmers would get from improved quality of electricity services.

1.2 The costs -- in power outages, damaged pumping equipment, irrigation foregone because of power losses, distorted investment patterns, among others – exact a heavy toll from ordinary farmers. In the form of deficits, the subsidies also sap state budgets of funds that could otherwise be invested in rural infrastructure, extension services and advanced agricultural technology. As unrecovered costs, they starve suppliers of funds for maintenance and improved service. On the other side of the coin lie the benefits that reliable flows of power and good quality of other electricity services could deliver to rural India.

B. Overview

1.3 ***Reform remains distant.*** The Chief Ministers in 1996 set a goal: "bringing tariffs "to 50% of the average cost [of supply] in not more than three years". Two years later, the Government of India (GOI) facilitated this goal by introducing the Electricity Regulatory Commission Act, 1998. It is an attempt to depoliticize tariff setting by permitting states to establish independent regulatory commissions. While virtually all states have now instituted such commissions, only Haryana, Andhra Pradesh and Rajasthan have actually adjusted agricultural tariffs. No state is close yet to the target of fees that match half of supply costs, and at the other end of the spectrum, Tamil Nadu and Punjab continue to supply power to rural users free of charge.

1.4 The slow and very uneven progress of reform to a considerable degree reflects political uncertainty and opposition linked to the expectation that higher electricity costs would harm Indian farmers, a very large voting group in state after state, while better-managed state-owned utilities would be able to curtail the petty and not-so-petty theft of power by industry, commercial establishments and households. Political parties now in opposition, therefore, may see opposition to power sector reform as a means of boosting their popularity with key constituencies and influential vested interests – not least, the wealthier farmers who are also the largest users of cheap agricultural power. The pattern of political calculations, however, is so uneven that the out-of-power party denouncing proposals for change in one state is, as the ruling party in a neighboring state, an advocate of reform.

1.5 ***The politically sensitive subsidies carry heavy fiscal consequences***, first, for revenue-starved utilities and, second, for state treasuries obliged to make good the utilities' losses. The FY2002 deficit traceable to cheap power is estimated to amount to 1.2% of GSDP in Andhra Pradesh and 1.5% in Karnataka. High subsidies result in demand too heavy for under-financed utilities to satisfy. They also produce such heavy fiscal pressure on state governments that rural communities are starved of investments both in power and in overall agricultural infrastructure, research and extension services.

1.6 Moreover, the presumed beneficiaries – farmers who irrigate their land with electric-powered pumpsets – actually incur a variety of indirect costs attributable to the subsidies: sharp fluctuations in voltage, for instance, frequently burn out the pumps' motors, loss of production. To forestall such trouble, many irrigators buy robust but less efficient motors with thicker armature coil windings that can handle ups and downs in power flow. They also over-invest in horsepower, choosing, for example, a 10 hp motor when, if voltage were high and steady, and availability of power reliable, half that power would be adequate. (Padmanabhan and Govindarajalu 1999) Some who can afford the expense acquire diesel pumps and tractors as back-up machinery.

1.7 Utilities unable to handle the demand and, in particular, to keep to their promised schedules for supplying power to designated areas penalize farmers by denying them water at the time of irrigation peaks when it is most needed and the reliable service required to plan and carry out such activities as labor, canal maintenance, etc. Power outages and rationing are one cause. But farmers also lose time in repairing and reinstalling motors that burn out and in organizing alternative sources of water for their fields. In terms of time lost, the cumulative consequences can be as severe as a prolonged outage. And, without the income that reasonable power tariffs could produce, utilities become, at worst, unviable and, at least, unable to invest steadily in improving the conditions of power supply to consumers. For agricultural consumers, states and for suppliers of electric power, India's subsidized tariffs have become a lose-lose proposition.

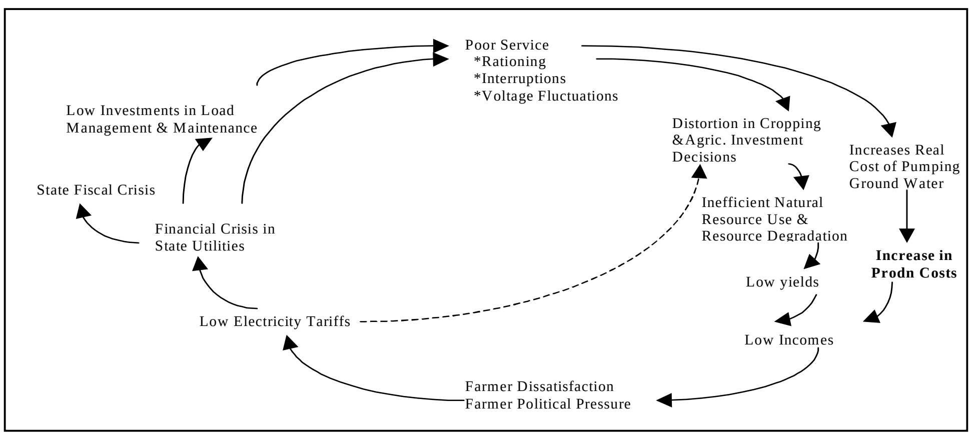
1.8 ***The situation has acute consequences for irrigated agriculture and economic growth.*** Power is essential for pumping groundwater for irrigation, and of total net irrigated area in Haryana in FY1997, about half used ground water extracted by pumpsets. In Andhra Pradesh (AP) in FY1999, 42% of net irrigated area was served by groundwater, also using pumpsets, the majority of which in both states run on electricity. The agricultural sector contributes a significant share to the States' Gross Domestic Product (GSDP), amounting to 35% and 28% respectively in FY1999 and employs the majority of the labor, about 60%, in both States. Over 70% of the population in Haryana and AP reside in the rural areas, which are also home to the majority of the poor – 70% in AP and 80% in Haryana as of FY1994 (World Bank 1998). Continued agricultural growth is therefore critical not only to sustain economic growth, but also to reduce poverty by driving rural employment and income growth.

1.9 Notably, agriculture's contribution to the GSDP in both states over the last few decades has been bolstered by the expansion of irrigated agriculture. Increased access to irrigation helped sustain yield growth and the increased diversification of production into such higher value crops as oilseeds, cotton, fruits and vegetables. The agricultural performance of these states also has important spillover implications for overall national food security. Haryana and Andhra Pradesh are two of the major surplus producers of basic staples. While accounting for only 1% of the land area in India, Haryana produces about 7% of the rice and wheat. Andhra Pradesh, with 8% of India's land, grows 10% of the national rice production, Adoption of improved technologies and increased access to irrigation, contributed to the sustained growth of the agricultural sector in these States. Continued electricity subsidies at unmanageable levels, that threaten the State's fiscal health, however, also crowds out productivity enhancing public investments needed to sustain agricultural growth.

1.10 ***Subsidized electricity fosters excessive use of water for irrigation, degrading a vital natural resource.*** The flat rate that most farmers in Haryana and all farmers in Andhra Pradesh are charged encourages them to pump water– rather than conserve it -- whenever they can and in whatever volume is possible. The result is inefficient on-farm use of water, leading in an increasing number of cases to over-extraction and declining water tables in the more water scarce areas. Since the flat tariff does not reflect the true scarcity value of water and power, it also distorts crop choices in favor of more water intensive crops (e.g. sugarcane). In several parts of India, the water table has declined. As over-exploited ground water blocks increase, so does the demand for power to draw water up from deeper in the soil, putting future agriculture performance in jeopardy.

1.11 ***The current crisis in agricultural power supply represents a vicious circle, a low equilibrium trap*** (Figure 1.1). From the utility's point of view, providing agricultural power costs more than supplying industry because the fixed costs per hook-up of serving connections spread across the countryside and the line losses are much higher. The political pressures that have resulted, over time, in increasing subsidization of electricity tariffs to agriculture have made many of the electricity utilities unviable and resulted in low capital investments without which reliability suffers. Distribution losses due to widespread pilferage further exacerbated the situation, the resultant inadequate and deteriorating quality of supply of electricity to farmers, the frequent power outages and voltage fluctuations. As a consequence, consumer dissatisfaction increased and, with it, unwillingness to pay even highly subsidized charges. As users often postpone paying electricity bills and resist tariff revisions, cost recovery diminishes for the utility, further perpetuating the circle.

Fig 1.1 - Power Supply to Agriculture: The Vicious Circle



1.12 This report examines the situation in Andhra Pradesh and Haryana, two of the six states that worked or are working with World Bank assistance to reform the power sector. Karnataka, Orissa, Rajasthan and Uttar Pradesh are the others. In all of them, subsidy reductions are integral to reform agendas that envision independent regulation, privatized, commercial operations to distribute and supply power, more competitive power markets, and a restructured, efficient power sector free of political interference. Urgent as tariff reform is, however it is also arouses anxiety and concern. That apprehension among policymakers flows from a lack of information and a presumption that higher tariffs will harm the income and welfare of farmers.

1.13 ***While agriculture is a major consumer of power, its consumption levels are being grossly over-estimated.*** Accounting practices have continuously disguised non-technical losses (essentially pilferage) as consumption of power by agriculture. Since a large part of the supply to agriculture is unmetered, utilities can under-report the systems' actual distribution losses by ascribing a significant portion of non-technical losses and theft as agricultural supplies. As a result of overstating agricultural consumption and using flat rates, actual unit tariffs to agriculture are higher than nominal tariffs, non-technical distribution losses are higher than reported. Ultimately, subsidies expected to benefit the poor farmers in fact benefit the large farmers and the pilferers of power, many of them not being farmers. While this reality is well known, existing estimates[1] are largely based on anecdotal evidence or non-representative samples.

1.14 ***In the absence of reliable data on rural power supply, guesswork replaces precise assessments of the possible impact of alternative reform options on farmer incomes.*** To address this knowledge gap, the Governments of Andhra Pradesh and Haryana and the World Bank, undertook a collaborative study that examines the nature, performance and impact of current power supply conditions on agriculture in the two States. The three following chapters present findings from that investigation on the conditions under which power is supplied to agriculture, the impact of such conditions on farming efficiency and incomes and the extent to which power sector reforms would affect farmer welfare. The next chapter examines levels of agricultural electricity consumption, highlighting the differences between utility estimates and a metering study of a representative sample of Haryana farmers. It also describes the quality of agricultural power supply in terms of availability, reliability and degree of voltage volatility. The third chapter focuses on the ways electricity is employed for farming and the impact of the existing electricity tariff structure and quality of supply on farm activities and incomes. The last chapter discusses a set of power policy measures that would aim at improving the quality of electricity services to rural areas and realizing the potential benefits for farmers , as well as complementary reforms in the agricultural sector.

1.15 This report draws heavily on the findings of a number of studies, involving primary data collection, conducted as part of the joint Government of Haryana and Andhra Pradesh and World Bank research initiative. It included a (i) a metering study of pumps owned by farmers; (ii) feeder study; and (iii) farmer household surveys (electric and diesel pump owners, canal users, water purchasers and rainfed farmers) in Haryana and Andhra Pradesh (Box 1.1). Two state reports, “Power Supply to Agriculture: the Case of Haryana” and “Power Supply to Agriculture: the Case of Andhra Pradesh” contain more detailed discussion of the results of these studies. An additional report, Methodological Framework and Sampling Procedures, deals with the theoretical model underpinning the policy analysis, and the sampling methodology and analysis adopted for conducting the survey and the metering studies.

Box 1.1 - Background Studies Completed

Metering study monitored consumption of power of a representative sample of 584 pumpsets in Haryana, initiated in November 1998 and still on going.. Electronic meters, measuring the quality of power, were installed on 60 of the pumpsets.

Farmers’ household surveys, included: (i) attitude surveys of 687 farmers Haryana and 525 farmers in Andhra Pradesh to assess their views on the supply of power to agriculture; and (ii) Recall surveys covering representative samples in both states of electric and diesel pump owners, canal users, water purchasers and rainfed farmers, including 1,659 farmers in Haryana and 2,120 farmers in AP. Data collected over the full crop year were for Rabi season (December 1999-April 2000), the summer season (June-July 2000); and the Kharif season (August-November 2000) in Haryana. In AP, the surveys covered the summer season (April-June 1999), Kharif season (June-November 1999) and Rabi season (December 1999-April 2000).

Feeders’ studies monitored power supply availability, reliability and quality in four feeders (Kalyana, Nalikalan, Janesroan, and Khijuri) in Haryana using meters with data logging facility that could record voltage and currents at five-minute intervals. Data were collected during Kharif season 1999, and Rabi season 2000.

Econometric Analysis used the primary data collected above to gauge the impact of current power supply conditions on farmer irrigation technology choices, farm incomes and electricity demand. Existing conditions of electricity supply are likely to affect farmers in several ways. Over the long run, farmers are likely to choose the irrigation technology that maximizes the expected discounted value of future returns subject to the constraints that they face. Once these technology decisions have been made, then during any given season farmers choose: (i) how much land to cultivate: (ii) what crop-mix to grow; and (iii) how many variable inputs (including electricity) to apply. All these input and output choices, in turn, determine farm incomes in each season. The parameter estimates obtained from the econometric model are used to conduct various policy simulation exercises.

[1] See for example works carried out by M. Moench and T. Shah in Uttar Pradesh and Gujarat.

CHAPTER 2

POWER SUPPLY TO AGRICULTURE IN HARYANA AND ANDHRA PRADESH: STATUS AND PERFORMANCE

A. Introduction

2.1 For policymakers to understand the costs, benefits and consequences of reforming agricultural power tariffs and the structure of the electric utility system, they need an accurate assessment of the system's current performance. This chapter discusses the findings of a number of surveys that measured power consumption, losses, reliability, availability and quality in Haryana and in Andhra Pradesh. On all counts, the existing arrangements disserved both suppliers and consumers.

2.2 Indicative of the information gap in the field is the finding that, in Haryana, irrigation pumps, on average, are using only three-fourths the amount of power suppliers estimate they consume, meaning that actual losses including theft and pilferage is more than 15 percent above official estimates. The resulting annual revenue loss runs to about 7 billion Rs in Haryana. In Andhra Pradesh, utilities would lose Rs. 1.2 billion for every percentage point underestimate of loss. The utilities, moreover, are not delivering power to farmers in the amounts promised, at the times promised or of the quality needed to preclude equipment failure. Losses to farmers include the cost of lower crop yields due to irrigation activities skewed by shortfalls in the supply of electricity and the expenses of repairing machinery (as well as having it out of service) because of the damage done by voltage fluctuations. Also indicative of the information gap is the finding that the cost of motor burn-outs is equivalent to the electricity bill of the farmers.

B. Agricultural Electricity Consumption in Haryana

2.3 ***How much electricity does the agricultural sector actually consume?*** This issue has been the subject of continuing controversy in most states in India. Arising from the procedure that utilities adopt in estimating agricultural consumption, the dispute centers on estimates of non-technical losses—particularly theft and pilferage of electricity, which many claim are "hidden" under the agricultural consumption that is estimated rather then metered [2]. In Haryana, for example, because there are both metered (20% of the total 370,000 connections) and unmetered (80%) agricultural consumers, unmetered consumption is estimated by applying a standard average number of hours of pump use per month by the number of agricultural pump users [3].

2.4 Total agricultural consumption is the sum of metered and estimated unmetered consumption, and distribution losses are then estimated by deducting agricultural use and the metered consumption of non-agricultural consumers (residential, industry, etc.) from total power flowing through the distribution network. A precise estimate of the non-technical losses is vital for several major reasons: the presumed quantity of lost revenues that could alleviate the utilities' financial difficulties, the effect of the losses on cost estimates for supplying electricity to rural areas, and the assessment of the beneficiaries of subsidies. Accurate, rational estimates are critical to formulating appropriate and sustainable pricing, subsidization and cost recovery policies and to combating theft and corruption.

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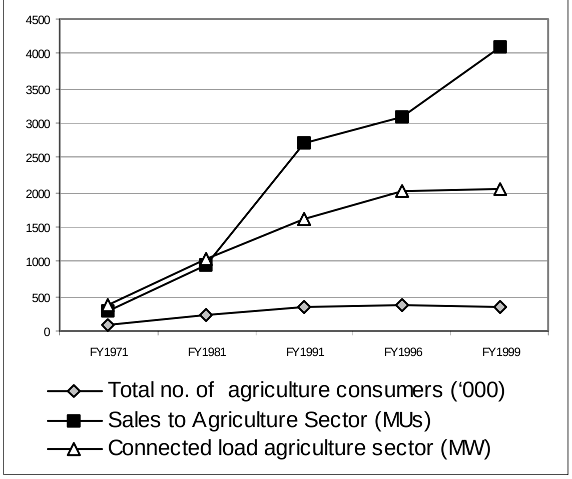
[2] During the mid seventies to early eighties, most of the State Electricity Boards in India shifted away from metering electricity sales to agricultural consumers and introduced tariffs based on capacity of the pumps. This shift was apparently a matter of administrative convenience meant to minimize costs involved in metering, billing and collection from agriculture consumers scattered in remote areas. Among the states with high electricity consumption in the agriculture sector, Andhra Pradesh, Uttar Pradesh, Punjab, Tamil Nadu, and Karnataka do not meter any agricultural connections. Rajasthan is the only state which has about half of its agriculture connections metered, but they account for only one-fifth of the total electricity sales to agriculture consumers. Haryana, Maharasthra and Kerala also have some metered agriculture connections.

[3] The Haryana utilities are using standard figures for each district. The average standard of hours of pump usage for Haryana as a whole is 6.7 hours.

Agricultural Power Consumption: Official vs Study Estimates

2.5 ***Official estimates assert that Haryana's agricultural electricity consumption rose more than 13-fold during the last three decades.*** Growing at an average annual rate of about 10%, even faster than total electricity consumption (8%), it spiraled up from 299 GWh in FY1981 to 4,400 GWh in FY1999 (Figure 2.1). Agriculture's share of total use is thus said to have increased from 31% to 46% during the same period, even though the number of agricultural consumers grew only four-fold, from 86,000 to 359,000. These estimates translate to a more than three-fold increase in consumption per electric pump from 3,477 kWh to 11,393 kWh per year over the three decades, a boost in use that supposedly can be traced largely to the adoption of the flat rate tariff in 1978. That reasoning would seem plausible if the estimates were credible. Their realism, however, is decidedly suspect.

Figure 2.1 - Government Estimates of Electricity Consumption by Agriculture in Haryana



Source: Haryana Vidut Prasaran Nigam, Ltd.

Box 2.1 - A note on the Sampling Methodology for the Metering Study

The Sampling Methodology used for metering and recall survey is based on sound statistical principles to ensure that the estimates of parameters obtained are valid and reliable to the extent possible within the resources available for the study. The main objective of the study was to estimate power consumption in agriculture at the state level. It was also desired to estimate the T&D losses, particularly the losses on account of theft, pilferage, etc. For this purpose, a stratified two stage random sampling was used which is by the most commonly used design as it provides estimates which have all the desired properties like unbiasedness, consistency, good precision, etc. with a reasonable sample size. Stratification was done on the basis of characters highly correlated with power consumption (cropping pattern, rainfall, source of irrigation, etc.) which is bound to improve the precision of the estimates without any increase in the sample size. In Haryana, the sampling design adopted for the study catered to both these objectives. The design also provided a representative sample of the units at various stages since selection of units at all the sampling stages was done with equal probability without replacement i.e. all units in the population (feeders/villages in a region, transformers/tube wells in a feeder/village) had an equal probability of being selected in the sample. This also holds for the recall survey for which also the sampling design was the same. The sample size was determined on the basis of universally accepted criteria of Coefficient of Variation (CV) and Relative Error. Since no study has been carried out in the past on the variability of power consumption by tube wells at the district or state levels and therefore no prior idea of CV was available, a reasonable value of 0.3 for the CV was assumed to work out the sample size. Even though it was felt that the number of feeders in the study on metering should be increased, HVPNL showed their inability to cover a larger number of feeders within their available resources for recording meter readings at fortnightly intervals. The estimated power consumption in Haryana has a sampling error of about 12% as against 5-6% aimed at in the planning stage. This is because the actual CV in the consumption data based on meter readings was much higher. To obtain the estimate of power consumption with sampling error of 5-6% (half of the estimated S.E), the sample size would have to be 4 times of that taken in the study. The same result is obtained if we double the value of CV in the expression of sample size. The confidence interval for the estimated power consumption per pump at the state level in Haryana works out to 8151 +- 1995 KWh while that for the total consumption comes to 2876 +- 704 GWh. Similar values can be worked out at the region level using the formula (x +- 1.96 s) where x is the estimated value and s its standard error.

2.6 To develop a more precise estimate of agricultural power use, the Government of Haryana and the World Bank initiated a program to measure with meters the electricity consumption of a representative sample of farmers in the state. The sample included 584 farmers, connected to 25 feeders covering the state's five agro-climatic regions. Electricity consumption was monitored for one crop year (Summer, Kharif and Rabi seasons), with utility staff taking meter readings fortnightly. Rigorous statistical methods, discussed with the utilities, the Haryana Agricultural University and state departments of agriculture, irrigation and power were used to select the feeders and the farmers to ensure the statistically best representation of the overall population of farmers using electric pumpsets in Haryana.

2.7 ***Official estimates of electricity consumption per pump far exceed estimates of actual consumption.*** On average, the electricity consumption per pump as estimated in the joint metering study is 8,150 kWh in FY2000 (Table 2.1). This is significantly below the standard used by the state utility, the Haryana Vidut Prasaran Nigam Ltd (HVPNL), of 12,469 kWh per pump for FY 2000. Varying through the seasons, consumption rates per pump were highest in the Kharif season (3,697 kWh/pump), largely due to the predominance of rice cultivation, a very water-intensive crop. Consumption rates also varied significantly from region to region, reflecting different cropping patterns and agro-climatic conditions and therefore demand for irrigation (See Chapter 3).

Table 2.1 - Metering Study and HVPNL Estimates of Electricity Consumption per Pump (kWh/pump) and Hours of Use per Pump FY 2000

Season	Electricity Consumption Per Pump by Region, kWh/pump					
	I	**II**	**III**	**IV**	**V**	**All**
Summer	3,123	1,500	736	1,490	**3,540**	1,855
Kharif	5,728	3,092	2,532	2,281	**7,503**	3,,697
Rabi	3,392	1,251	1,289	3,764	**5,100**	2,622
Total FY2000	**11,842**	**5,868**	**4,621**	**7,630**	**15,978**	**8,150**
HVPNL						12,469
	Hours of Pump Usage per Year by Region (hrs)					
	I	**II**	**III**	**IV**	**V**	**All**
Metering Study	**1,448**	**1,417**	**1,094**	**1,564**	**1,732**	**1,500**
HVPNL-metered customers	1,486	1,344	1,463	1,481	1,371	1,438
HVPNL-unmetered customers	2,694	2,105	2,783	2,801	2,675	2,463

Source: Haryana Metering Study and HVPNL

2.8 **Hours of Pump Usage.** Official estimates of hours of pump use by metered farmers is very close to study estimates – a 4% statewide difference (Table 2.1). This is not the case for un-metered farmers: official records significantly overestimate consumption by un-metered farmers and, therefore, agricultural consumption overall. The degree of disparity, however, varied considerably across regions with HVPNL estimates higher in Regions I and III and lower in III, IV and V. The utility's estimates of hours of pump usage for unmetered farmers were consistently and significantly – 64% **--** above study findings of actual farm use, 2,463 hours in FY2000, compared to the metering study estimate of 1,500 hrs. The degree of over-estimation of consumption by unmetered farmers ranged from 49% to 154% across regions of the consumption estimates under the study. Note that the amount consumed by the unmetered agricultural consumers was assessed based on some assumption of the number of hours of pump use defined for each circle [4]. Where HVPNL estimates consumption of electricity at 4,400 GWh in FY 2000, the metering study indicates consumption of 2,876 GWh, is 35% lower than the utility estimates. The standard error of this estimate is 12.5%.

2.9 Although the sample selection and procedures to be adopted were originally discussed and agreed with the Government of Haryana and the power utilities, Haryana has disputed the validity of the above results because of the small size of the sample and the procedure followed. Haryana's comments have been reproduced in Annex 8 of the Haryana Report. As presented in Box 2.1, the sampling procedures adopted for the study are based on sound statistical principles and the estimates of the parameters are valid and reliable given a reasonable sample size.

[4] A circle is an administrative and operation area unit within the distribution utilities. There are 13 circles in Haryana and 23 in Andhra Pradesh.

2.10 **Transmission and Distribution Losses: Official and Study Estimates.** The metering study's lower estimate of agricultural consumption implies that transmission and distribution losses of 7,132 GWh are also significantly (27%) above official estimates of 5,607 GWh. The higher, formerly unaccounted-for T&D losses, likely due to theft and pilferage outside of the agricultural sector, raises T&D losses to 47% of the total electricity available for sale[5] of 15,204 GWH in FY2000, instead of the 37% estimated by the HVPNL, or to lost revenues of about Rs. 7 billion (assuming Rs. 3.70 per kWh cost of supply). Strengthened collection efforts could therefore help considerably improve the financial health of the utilities. Based on revised estimates of electricity consumption by agriculture, their average per unit revenue would amount to Rs. 0.45/kWh. Further, if tariffs were charged on the actual level of connected load, which the metering study estimates to be on average 74% higher than the utility records, the average per unit tariff from agriculture would be about Rs. 0.78/kWh, recovering about 21% of the average cost of supply.

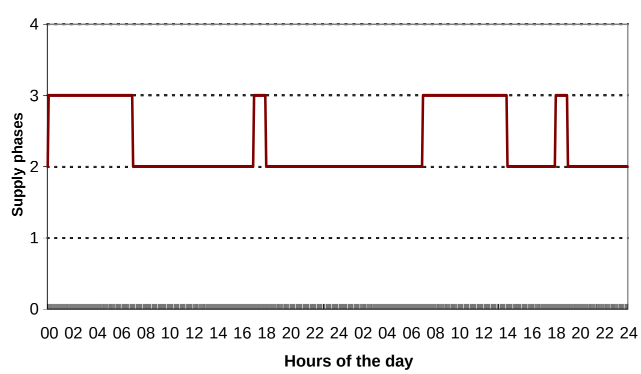
C. Availability and Reliability of Power Supply to Agriculture

2.11 ***Rostering, a method of allocating power supply to agriculture, adopted by the Indian utilities,*** involves supplying power only during pre-announced and restricted hours a practice that makes the utility's performance in maintaining its schedule critical for farmers. They require reliable power to insure adequate supply of water, particularly during critical growth periods when delays could adversely affect crop performance and yields. The feeder and metering studies, however, find that stated utility policy is not reflected in the reality on the ground.

2.12 Given power shortages and competing demands for electricity by different sectors, most Indian utilities today try to manage supply, especially during peak demand, using peak load restrictions, power cuts, staggering of holidays for the industrial sector; power cuts or load shedding for domestic and commercial categories. Rostering for the agricultural sector generally involves: (i) dividing farmers into groups and (ii) supplying power (outside of peak load periods) to a particular group only for a fixed number of hours at a pre-announced "scheduled" time of day or night[6].

2.13 Rostering procedures vary from state to state and season to season within states but uniformity is maintained within the districts. During the Kharif and summer seasons 1999, for example, power flowed for 16 hours (8 & 8 hours) over two days to both the double and single crop areas (Figure 2.2). During the Rabi season 2000, the schedule was revised: 18 hours (10 & 8 hrs alternately) for single crop areas and 16 hours (9 & 7 hours alternately) for double crop areas. By contrast, in Andhra Pradesh, no distinction is made among areas or crops. Farmers are divided into two groups, rotating every two days, following a schedule of 9 hours of three-phase supply (6 & 3 hours), 9 hours of two-phase supply and 6 hours without power (Figure 2.3).

Figure 2.2 - Power Supply Rostering in Haryana for the Kharif season



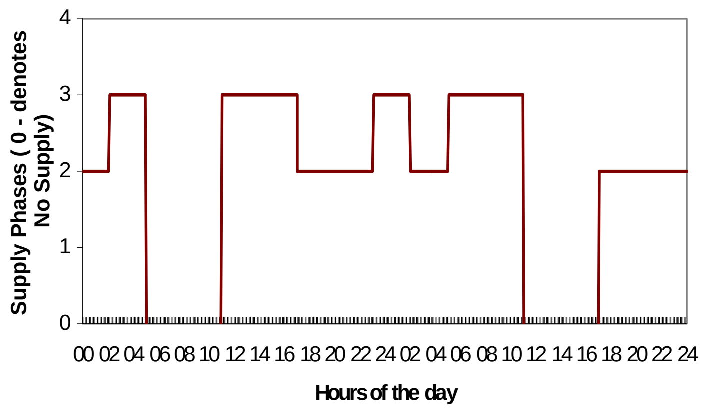
Source: HVPNL

[5] Total electricity available for sale is defined as the sum of electricity purchased in bulk by the state generation stations, central generating stations, and IPPs from other states.

[6] To implement this rostering practice, the utilities use technical mechanism to supply three-phase power when the power is to be used for irrigation purpose and one or two-phase power otherwise. The report on "The supply of Power to Agriculture in Haryana" further details this mechanism, probably unique to India.

2.14 ***Farmers in Haryana, however, report receiving fewer than the scheduled number of hours of power supply.*** According to the results of the recall survey conducted in 1999-2000, farmers said that during the summer and Rabi seasons they received less than the stated 8 hours of supply announced by HVPNL. Respondents confirmed frequent power cuts, even during scheduled hours, ranging from about 2 to 3.3 hours. On average, farmers reported that the three-phase supply was available for 6-10 hours per day with the major exception of the 1999 Kharif season when supply was higher than the scheduled hours of supply in several regions. This unusual service was partly explained by the State elections held during this period.

Figure 2.3 - Power supply Rostering in Andhra Pradesh

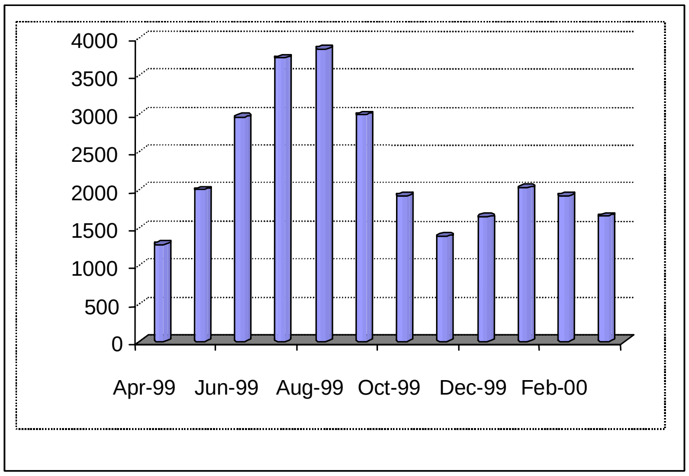


Source: APTRANSCO

2.15 The farmers' reports were generally confirmed by a 1999-2000 study conducted at four Haryana feeders where electronic meters gauged the availability and reliability of actual power supply during the Kharif and Rabi seasons. The most obvious finding was the lack of uniformity in either measure with power available at some substations for 3.6 hours a day and, at others s, for 23 hours. During Kharif, there were days and places when power flowed for only a single hour, compared to the prescribed eight hours at other locales or in other 24-hour periods. During the Rabi season, power supply did not once coincide with the schedule; reliability ranged from 80% to 94%, from 6.6 hours in a cycle to 7.5 hours. Such instability can impose significant costs on farmers if it prevents irrigating during critical periods in the plant growth cycle, thus affecting crop yields. The report on Haryana provides detailed supporting evidence.

2.16 **Transformer Burnouts.** One important cause of unreliable power delivery and erratic availability is transformer failure, burnouts due to overloading and unbalanced loading, to poor maintenance and protection, and to lightning strikes. Long delays in repairing the transformers – 26% of which fail in Haryana in FY2000 -- compound the injury to farmers and, by increasing the utilities' operating cost, further aggravate their poor financial health. With about 107,000 transformers as of March 2000, Haryana experiences higher transformer failure rates in rural areas than in urban ones and, the failures tend to peak during the months of July and August of the Kharif season, when the irrigation requirement is highest and thus agricultural demand on the system is also very high (Figure 2.4). With paddy as the main crop, all pumpsets virtually work simultaneously, whenever power comes on stream, putting a tremendous load on transformers that could

Figure 2.4 - Transformer Burnout in Haryana by Month, April 1999 to March 2000



Source: HVPNL data

be a significant contributor to their failure. In addition, during the Kharif season, overall system load demand increases significantly on account of demand from other sectors, especially for air conditioning, because of higher humidity and temperatures. Thus, the (monthly) failure rate of transformers in these two months rises above 3.5%, while during the rest of the year, it is equivalent to around 1.5 to 2%.

Table 2.2 - Frequency Distribution of Transformer Burnout per Year by Village, 1999-2000

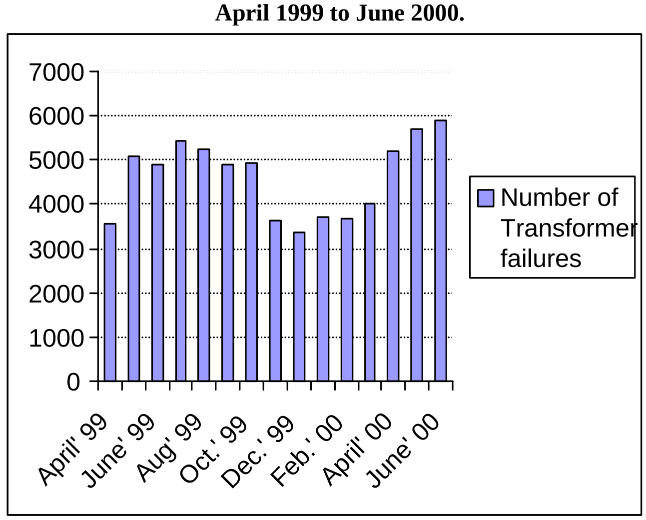
REGION	Number of Transformer Burnouts (Percentage Distribution)							Total Number of Villages
	0	1	2	3	4	5	6	
1	4.0	28.0	48.0	16.0	0.0	4.0	0.0	25
2	0.0	24.1	55.2	13.8	0.0	6.9	0.0	29
3	17.9	17.9	10.7	21.4	14.3	10.7	7.1	28
4	6.9	6.9	34.5	6.9	20.7	13.8	10.3	29
5	0.0	29.6	25.9	29.6	7.4	7.4	0.0	27
Total	5.8	21.0	34.8	17.4	8.7	8.7	3.6	138

Source: Village Survey

2.17 In focus group surveys conducted in villages as part of the Haryana Farmer Recall Survey, farmers in almost every village (94%) reported at least one transformer burnout during the year and those in about 40% of the villages reported 3-6 such failures. (Table 2.2) About 73% of the villages reported multiple transformer burnouts, with half having to bear 2-3 burnouts per year. The same survey also found farmers aware of the major causes of transformer burnouts, with about 83% citing short-circuiting as a factor, 79% blaming the use of pumps with higher horsepower than had been reported to the utilities and 67% citing connections in excess of the transformer's capacity.

2.18 ***In Andhra Pradesh, the incidence of transformer burnout is even higher than in Haryana, but the duration of repair delays is shorter.*** During FY2000 the rate of transformer burnout was 29%. Figure 2.5 shows the month-wise distribution of transformer failures peaking during July-August as in Haryana. The high burnout rate is partly due to over-loading problems, caused both by too many pumps being connected to the transformer and the use of higher hp pumps than the hp registered. During the Kharif seasons, short circuits were also reported as a cause of transformer burnouts.

Figure 2.5 - Transformer burnout in Andhra Pradesh by Month, April 1999 to June 2000.



Source: APTRANSCO data

2.19 Getting broken transformers back on line quickly is critical to resuming water supply and shielding farmers against potential losses of yield and income. In Haryana, although the frequency distribution of transformer burnout is lower than AP's, it takes HVPNL longer to resolve the problem. On average, the utility needs 10 days to repair a transformer during the Kharif, 8 days during the summer and 6 days during the Rabi (Table 2.3). By contrast, APTRANSCO takes less than one third of the time to repair the transformers, on average 2.3 days during the Kharif and summer and 1.8 days during the Rabi season (Table 2.3).

Table 2.3 - Frequency of Transformer Burn-outs and Time Taken for repair in Haryana and Andhra Pradesh

Haryana						
Average Frequency of T/F burn-out per season	**I**	**II**	**III**	**IV**	**V**	**All Regions**
Rabi	0.4	0.5	1.1	1.2	0.8	0.8
Kharif	0.8	0.9	0.9	1.1	1.0	1.0
Summer	0.6	0.7	0.6	0.9	0.5	0.7
Average number of days taken to resolve problem (days)						
Rabi	4	3.6	8.8	7.8	7.9	6.4
Kharif	8.5	10.5	10.4	10.1	11	10.1
Summer	8.3	9.6	5.7	9.6	6.4	7.9

Andhra Pradesh							
Average Frequency of T/F burn-out per season	**I**	**II**	**III**	**IV**	**V**	**VI**	**All Regions**
Rabi	2	3	2	2	3	3	3
Kharif	1	1	2	2	2	2	2
Summer	2	3	2	3	4	4	3
Average number of days taken to resolve problem (days)							
Rabi	3	3	4	5	5	5	4
Kharif	3	2	3	4	4	3	3
Summer	4	4	4	4	5	5	4

Source: Haryana village questionnaire and Andhra Pradesh Farmer Recall Survey.

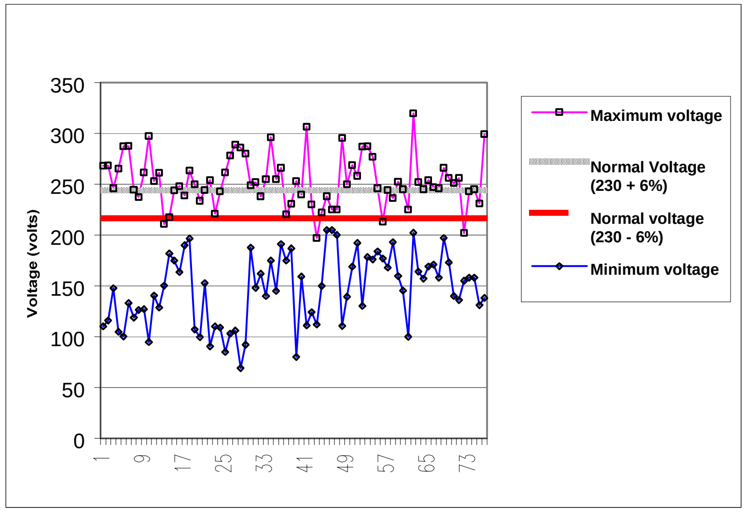
D. Quality of Power Supply to Agriculture

2.20 ***Quality, in terms of voltage profile and imbalances, is another critical dimension of power supply where performance is extremely poor.*** The metering study shows the voltages of power supplied to agriculture fluctuating frequently and over a wide range while three-phase power supply is subject to significant imbalances. This low quality significantly affects the life of electric pumps and their operating efficiency. One of the major factors contributing – along with the general condition and design of the motor -- to pump motor burnouts, voltage fluctuation is a hazard to which farmers tend to be particularly attentive[7]. But even knowing that poor voltage is detrimental to their pumps, they are forced in some instances to operate them, because the limited and restricted hours of power supply mean they cannot postpone irrigating their crops. Technically but at a high cost, the problem of voltage fluctuation can be solved by using a voltage stabilizer to the power supply connection.

[7] Some farmers use measuring devices like voltmeters to measure the voltage of power supply. Others are said to rely on visual dimming or brightening of a bulb installed at the top of the pumping house to provide an indication of power availability. (Haryana Attitude Survey 1998)

2.21 ***Farmers in all regions in Haryana reported frequent voltage fluctuations, an assessment confirmed by the metering study.*** About 94% of farmers responding to the survey acknowledged experiencing voltage fluctuations in both the Kharif and Rabi season (Table 2.4). The frequency of fluctuations varied across regions and seasons. During the Kharif season 1999, on average 71% reported daily fluctuations compared to 47% during the Rabi. Metering data back up their memories. Figure 2.6, showing the range of minimum and maximum voltage levels recorded by electronic meters at the sample pumps, illustrates that contrary to general belief, the power supply to many electric pumps is not just at very low voltages but also at extremely high ones, much above the prescribed standard. The sample metering data indicate that the majority of the pumps more often receive power supply at lower voltages than the prescribed band of Normal –6% as per the Indian Electricity (Supply) Rules -- generally during the peak irrigation requirements. [8] However, farmers received power supply at normal voltages only 20% (in Region I) to 39% (in Region III) of the time only, and more than half of the time voltages were much lower than normal.

Figure 2.6 - Range of Supply Voltage Received at Pumpsets



Note: Samples with electronic meters: Samples 1-14 - Region I , 15-36 - Region II , 37-48 - Region III, 49-59- Region IV & 60-76 - Region V
Source: Haryana Feeder Study

Table 2.4 - Voltage Fluctuations Experienced by Farmers (percentage distribution)

Opinion Category	Region 1	Region 2	Region 3	Region 4	Region 5	All Regions
Kharif season – recall survey						
% Farmers experienced voltage fluctuations	97.7	99.0	89.3	91.1	74.6	93.7
Irregular	21.8	9.7	27.7	46.7	22.4	19.0
Fortnightly	3.4	3.1	0.0	2.2	0.0	2.2
Weekly	0.0	2.1	1.8	0.0	3.0	1.7
Everyday	72.4	84.0	59.8	42.2	49.3	70.8
Rabi season – recall survey						
% Farmers experienced voltage fluctuations	94.0	90.6	99.2	94.7	95.2	93.8
Irregular	21.7	43.5	0.0	13.5	3.2	23.4
Fortnightly	8.4	1.0	2.4	12.4	34.9	7.6
Weekly	9.6	5.4	34.4	20.0	25.4	15.8
Everyday	54.2	40.8	62.4	48.8	31.7	47.0

Source: Farmers' recall survey

2.22 ***Even at the sub-station level, outgoing voltage is generally lower than the rated supply voltage of 11 kV.*** In order to maintain voltage at the pumpset level within the prescribed limits of 230V +/- 6%, the outgoing voltage level at the substation end should be 7 to 8% higher than the normal 11 kV voltage level. The minimum voltage level recorded in one feeder, however, was as low as 60% of the rated requirement. During the period of analysis, the voltage profile was generally much better during the Rabi than the Kharif season in three of the 4 feeders. To what degree the high volatility of voltage levels affects the operations of farmer's pumpsets is analyzed more rigorously in the next chapter.

[8] Electrical equipment is normally designed to operate safely at a voltage level up to 10% higher than the prescribed one.

2.23 ***Imbalances in the three-phase supply of power are also a major problem for pump owners since this strains their motors and accelerate their burning-out.*** The three-phase power supply should carry equal voltage in different directions (phases) to each other in all three lines. Because it is more difficult for farmers to correct it, the effect of voltage imbalances between phases is more severe than that associated with low or high voltages. The metering study found that, except for Region V, more than 70% of the sample recordings showed farmers facing phase-to-phase imbalances greater than 3%, despite the fact that the safe imbalance band is 0-3% only. About 35% to 73% of the farmers in each region faced a maximum imbalance of more than double the safe limit, while about 9 to 36 % farmers faced phase imbalance of more than 30%.

CHAPTER 3

POWER SUPPLY: USE AND IMPACT ON FARM PRODUCTION AND INCOMES

A. Introduction

3.1 The debate over tariffs and state utilities turns on the question of how power sector reform program would affect the agricultural sector in general and farmers in particular? No precise answers, however, have been available because existing data have not measured the ways in which power supply now affects the productivity and profitability of the many farmers who depend on groundwater irrigation and use electric pumps to put water in their fields. To close this information gap and thereby facilitate formulating and achieving broad-based consensus on an agenda for power reform, the Governments of Andhra Pradesh and Haryana and the World Bank supported state-wide farm household surveys. These included (i) "attitude surveys" of 689 electric pump owning farmers in Haryana and 525 pump owners in Andhra Pradesh during the Rabi season 1998 to assess their perceptions on the supply of power to agriculture; and (ii) "farmer recall surveys" covering a state representative sample of electric and diesel pump owners, canal users, water purchasers and rainfed farmers, including 1,659 farmers in Haryana and 2,120 farmers in AP[9]. The recall surveys collected information on crop output, input use, electricity and water use, farm assets, supply and quality of power services, and various socio-economic variables. The report "Methodological Framework and Sampling Procedures", elaborates on the methodology used for the survey and describes the conceptual framework used in the econometric analysis of the data**.** Box 3.1 presents a note on the robustness of the results.

Box 3.1 - Robustness of Sample and Econometric results

The data collected through the recall surveys was cross-checked at several stages. First by the field supervisor at the collection stage and then at the data entry and data analysis stage. In case of inconsistencies and missing information, an attempt was made to send the questionnaire back to the field level. Given the size of the survey and problems of accessibility, particularly in AP, problems of inconsistencies and missing information could not be completely resolved. However, at the data analysis stage, a careful check for outliers and inconsistent data points was carried out. A table on basic summary statistics (such as mean, standard deviation and range) was computed for each of the important variables in the study and is reported in the annex of main state report. Since the recall survey could only be carried out twice in every season, some errors associated with reported recall of daily occurrences (such as input applications, indicators of power supply received) remain. For the econometric model, which is used as a basis for the policy simulations, several different specifications of the basic model were tried to check for the robustness of the results. Based on these different specifications, a range of estimates, for the policy impacts are presented. On the whole, the results were found to be quite robust across the different specifications, as evidenced by the rather narrow range of values within which these estimates (from the different specifications) fall. Separate regressions were carried out for different farm size categories and stability of estimates across these different groups was tested. Careful attention was also given to testing and correcting for biases arising from sample selection and potential endogenity of reported estimates. The statistical significance of the estimates are presented in the report and only estimates that were significant at 10% level were used in the policy simulation exercise.

3.2 The surveys find that although many farmers in Haryana and Andhra Pradesh rely on electric power to enable them to irrigate their crops --, about 45% of those in a sample group use electric pumps alone or in combination with diesel motors -- only about one in five of the poorest farmers with the smallest land-holdings use pumps. This distribution means that a larger share of the subsidies to agricultural power is going to larger farmers, most of whom are also likely to be better able to absorb any tariff increases. At present, the tariffs paid for power are regressive, taking larger shares of gross income from small and marginal farmers than from the more affluent.

[9] Data were collected over the full crop year. In Haryana, these were for Rabi season (December 1999-April 2000), the summer season (June-July 2000); and the Kharif season (August-November 2000). In AP, the surveys covered the Summer season (April-June 1999), Kharif season (June-November 1999) and Rabi season (December 1999-April 2000).

3.3 Additionally, flat-rate tariffs and the poor quality of power have distorted some investment decisions, encouraging the purchase of heavy-duty, high-horsepower even by the poorer farmers who actually invest on average in more horsepower per gross cultivated area than large farmers. Finally, all pump-owning farmers are paying for the poor quality of power supply in the expense of rewinding their motors at least once a year. This hidden cost attributable to voltage fluctuations, and one among other additional costs borne as a result of poor quality, adds between 23% and 33% to the nominal tariff in Haryana; and between 80 and 110% to the tariff in Andhra Pradesh, a range that suggests the margin for higher tariffs tied to the provision of higher quality and more reliable power.

B. Electric Pump Use in Haryana and Andhra Pradesh

3.4 **Classification of Farmers.** Since farmers in both states may have one or more sources of supplemental irrigation, the survey divided them into pump-owning and non-pump owning groups (Box 3.2), with the former using electric or diesel pumps or both.

Box 3.2 - Definition of Categories of Farmers

Pump owning:

1) Electric pump owners: those farmers who own electric pumps (either metered or not). These farmers are further classified into three categories:

- a) **Electric only**: those who exclusively own an electric pump, including those who may also purchase water
- b) **Electric and canal**: those who own an electric pump and uses canal water, including those who also purchases water
- c) **Electric and diesel:** those who own both an electric and diesel pump, including those who may also use canal and purchases water.

2. Non-electric diesel pump owners: those farmers who do not own any electric pumps but own diesel pumps. These farmers are further classified into two categories:

- a) **Diesel only**: those who exclusively own diesel pumps, including those who may also purchase water
- b) **Diesel and canal**: those who own a diesel pump and uses canal water, including those who also purchases water

Non-pump:

3. Non-pump canal users: those farmer who do not own any pumps but have access to canal water and may purchase water.

4. Non-pump water purchasers: those farmers who do not own any pumps nor do they have access to canal water.

3.5 Moreover, electric and diesel users may also have access to canal (surface irrigation) water. Some farmers rely solely on purchasing water and on canal water as sources of irrigation, and some exclusively on rainfall. As elaborated in Section D, access to alternative sources of water, especially canal, can have a significant impact on the overall cost of irrigation. The distribution of farmers in the study, according to their source of water is presented in Table 3.1.

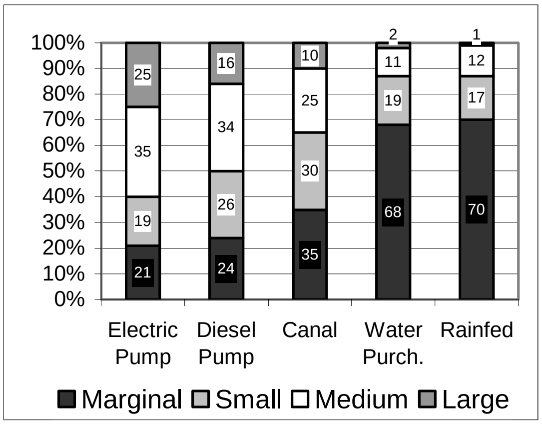
Table 3.1 - Distribution of sample farmers according to source of water in Haryana and AP

State	Electric pump owners				Non-electric diesel pump owners			Pure Canal users	Pure Water purchasers	Rainfed	Total
	Electric only	Electric and canal	Electric and diesel	Total	Diesel only	Diesel and canal	Total				
Haryana	482	59	236	777	74	175	249	251	245	137	1659
AP	886	30	0	916	259	6	265	434	204	301	2120

Source: Haryana and AP farmer recall survey

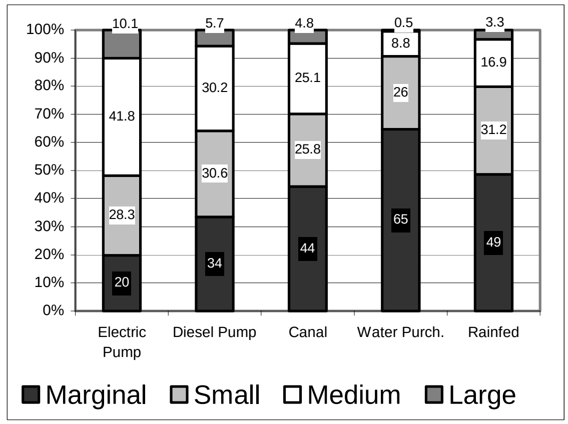
3.6 **Land Ownership.** ***A larger share of the electricity subsidy to agricultural sector is going to fewer farmers – the larger landowners who are also more likely to be pump owners.*** For the purposes of the study farmers in Haryana and AP were put into four categories depending on the size of their land holdings: (i) *marginal* for less than 1 ha; (ii) *small* for more than 1 but less than 2 ha; (iii) *medium* for more than 2 but less than 5 ha; and (iv) *large* for over 5 ha. The distribution of farmers by farm size and type of technology (or source of water) in Haryana and AP are shown in Figure 3.1 and 3.2. Notably, electric pump ownership is not confined to larger farmers. However, only about 40% and 48% of electric pump-owning farmers, respectively, in the Haryana and Andhra Pradesh were small and marginal. Only about 20% of the electric pump owners in the two states were marginal. This skewed distribution structure has a very important implication for the revision of electricity pricing policy: it is the larger farmers, who are also likely to be better able to absorb tariff increases, who receive most of the subsidies to agricultural power and benefit disproportionately from cheap power.

Figure 3.1 - Distribution of farmers by type of technology and land owned in Haryana



Source: Haryana recall survey.

Figure 3.2 - Distribution of farmers by type of technology and land owned in Andhra Pradesh



Source: AP recall survey.

3.7 The survey results suggest that electric pump owners tend to be wealthier than the other farmer categories, as measured by the amount of land they own. The average land owned by sample farmers in Haryana is 2.8 hectares (Table 3.2).

Table 3.2 - Average size of land owned by Type of Technology in Haryana, ha

Farm size Category	Electric pump owners				Non-electric diesel pump owners			Non-pump Canal Users	Non-pump Water purchasers	Rainfed	Total
	Electric only	Electric and canal	Electric and diesel	Total	Diesel only	Diesel and canal	Total				
Marginal	0.5	0.7	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.5
Small	1.5	1.2	1.3	1.4	1.3	1.3	1.3	1.4	1.3	1.4	1.4
Medium	3.1	3.2	3.2	3.1	3.0	3.3	3.1	3.0	2.5	2.9	3.1
Large	9.6	11.8	10.3	10.1	7.2	9.6	8.7	7.8	7.0	7.9	9.7
Overall	3.4	5.9	4.7	4.0	2.2	4.4	2.8	1.9	1.0	1.1	2.8

Source: Farmer Recall Data (Rabi 99-00)

3.8 Electric pump owners own the largest land on average (4 ha.), followed by diesel pump owners (2.8 ha.) and then pure canal users (1.9 ha.). Pure water purchasers and rainfed farmers own the smallest land (around 1 ha.). In AP, the average size of land owned by sample farmers was smaller, 1.8 ha (Table 3.3). The average size of land owned by electric pump users in AP is slightly smaller than in Haryana (2.2 ha), but is still larger than that in the hands of other types of farmers (diesel pump owners, canal users, water purchasers and rainfed farmers). The relatively small size of the average land owned in AP (1.8 ha) and across technologies (1.4 ha to 2.2 ha) is also consistent with the findings of other studies.

Table 3.3 - Average land owned by type of technology in Andhra Pradesh, ha

Farm Size	Electric pump owners			Non-electric diesel pump owners			Non Pump Users			Total
	Electric pumps only	Electric & canal only	Total	Diesel pump only	Diesel and canal	Total	Canal user only	Water purchasers	Rainfed	
Marginal	0.7	0.7	0.7	0.6	0.8	0.6	0.6	0.5	0.6	0.6
Small	1.5	1.4	1.4	1.3	1.4	1.3	1.4	1.3	1.3	1.4
Medium	2.8	3.2	2.8	3	3.7	3	3	2.7	2.8	2.9
Large	7.1	7.7	7.2	7		7	7.4	6.1	8.2	7.3
All	2.1	3.3	2.2	1.9	2.8	1.9	1.7	0.9	1.4	1.8

Source: Farmer Recall survey

3.9 **Pump Ownership: Who owns the electric pumps?** Larger farmers get the larger share of the electricity subsidy because, being more likely to own electric pumps and multiple pumps and pumps of higher hp, (see section on pump hp) they consume more electricity than others. About 11% of farmers in Haryana -- primarily medium and large ones -- owned more than 1 electric pump. (Table 3.4) Multiple electric pump ownership is more limited (about 3% of electric owning farmers) in AP, and as in Haryana, the owners are mostly larger farmers.

Table 3.4 - Percentage Distribution of Electric Pump Owning Farmers by Number of Electric Pumps Owned in Haryana and AP

Farm Size	Percent of Farmers in Haryana Owning Electric Pumps Numbering					Total
	Less than 1 pump	1 pump	Between 1 and 2 pumps	Between 2 and 3 pumps	Between 3 and 4 pumps	
Marginal	78.5	19.6	1.9	0	0	100
Small	59.2	35.9	4.9	0	0	100
Medium	36.8	52.5	8.0	1.5	1.1	100
Large	20.0	54.9	16.6	5.1	3.4	100
Overall	46.1	42.8	8.2	1.8	1.2	100

Farm Size	Percent of Farmers in AP Owning Electric Pumps Numbering				
	Less than 1 pump	1 pump	1 to 2 pumps	3 to 4 pumps	Total
Marginal	0.4	95.4	4.2		100
Small	0.7	98	0.7	0.7	100
Medium	1	94.2	4.8		100
Large		95.8	4.2		100
Total	0.7	95.8	3.3	0.2	100

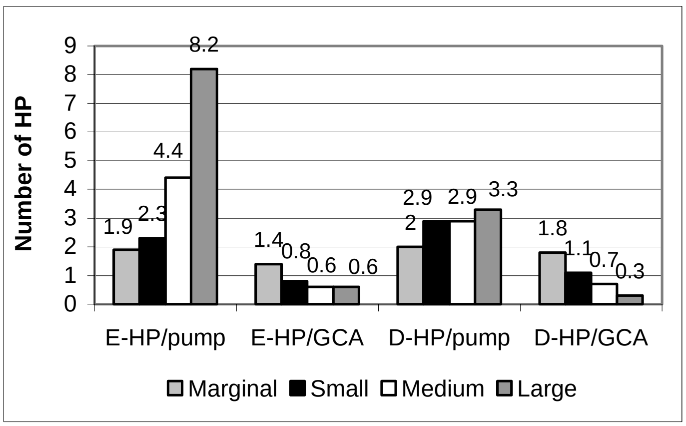
Note: Joint ownership: If a farmer has sole ownership of a pump and owns another pump jointly with an ownership share being ½ then the number of pumps owned by this farmer is taken as 1.5.
Source: Haryana and AP Farmers Recall survey.

3.10 **Joint Ownership of Pumps.** Joint ownership of pumps appears to be an important mechanism for enabling small and marginal farmers to gain access to an electric pump in Haryana. About one-fifth of the marginal farmers and one-third of small farmers in Haryana shared ownership rights to one or pumps with one or more other farmers. Joint ownership was also prevalent among larger farmers, about 56% of medium farms and 71% of large farmers report joint ownership on at least one electric pump. In Haryana, pumps could be co-owned with as many as 7 other farmers. On average, in the sample, pumps were co-owned with 3 other farmers. Across farm size categories, the number of co-owners was observed to be highest among marginal farmers. The number of co-owners decreased as farm size increased. For smaller farmers, joint ownership offers an important mechanism for overcoming at least partially the indivisibility and large capital that pump ownership requires. Inheritance of pumps could also be one important factor contributing to joint ownership. In Andhra Pradesh, only about 1% of farmers jointly owned pumps – all of them marginal to medium farmers.

3.11 **Ownership of Additional Diesel Pump**. In Haryana, in addition to owning electric pumps, 10% of the farmers owned an additional diesel pump, with the incidence of ownership tending to increase along with farm size. Small and marginal farmers accounted for only 11% of the owners of both electric and diesel pumps, probably because of the high capital and operating expenses required to buy and run the diesel equipment. In Andhra Pradesh, no farmers owned both an electric and diesel pump. In Haryana, however, the survey found a fairly straightforward correlation between diesel ownership and the availability, reliability and quality of power supply. The poorer the electric service on those counts, the more likely farmers were to invest in costly diesel technology even when they already owned electric pumps to cope with the poor conditions of power supply.

3.12 **Pump Horsepower.** If the quality of power supply drives the use of diesel as a back-up or supplementary irrigation technology, the power of electric pumps is generally dictated by two factors: what HP is available – the minimum pump size is 3 HP -- and what is needed to draw groundwater to the surface. Small farmers, for instance, may be compelled to purchase a larger pump than is economically justified by the area they farm, but large HP pumps may be a necessity in areas where water is farther below ground. Larger farmers in Haryana and AP tend to own electric pumps with higher horsepower. In Haryana, the average size of the electric pumps owned by small and marginal farmers was 1.9 and 2.3 hp, respectively, compared to 4.4 hp for medium farmers and 8.2 hp for large farmers (Figure 3.3). In AP, the average size of the electric pumps owned by small and marginal farmers was 4.8 and 5.0 Hp respectively, in contrast to 5.2 to 5.1 HP for medium and large farmers (Figure 3.4).

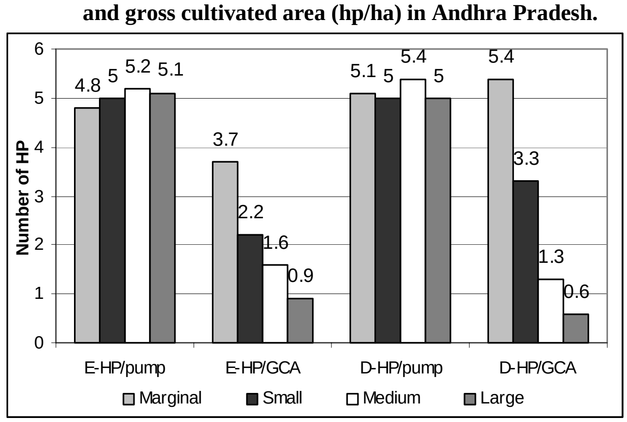
Figure 3.3 - Distribution of horsepower of pumps by farm size (hp) and gross cultivated area (hp/ha) in Haryana.



Note: E- electric pump, D- diesel pump, GCA-gross cropped area
Source: Haryana farmer recall survey.

3.13 In addition to unavoidable market and physical realities, however, small and marginal farmers, who tend to be more risk averse, may be investing in high HP pumps to cope with the limited availability and uncertainty of power supply by gaining the power to raise water faster and in greater volume when the power is actually on. In contrast to larger farmers who could invest in additional diesel pumps, smaller farmers are left to be more dependent purely on electric pumps. The supposed relationship between power supply and pump HP – until now based

Figure 3.4: Distribution of horsepower of pumps by farm size (hp) and gross cultivated area (hp/ha) in Andhra Pradesh.



Note: E- electric pump, D- diesel pump, GCA-gross cropped area
Source: AP farmer recall survey.

only on anecdotal evidence -- was tested through econometric analysis in Haryana. The study found that where power supply is more unreliable, farmers invested in higher HP pumps—the coefficients of unreliability of supply (as measured by the hours of power cuts per day during the scheduled period) during the two main growing seasons of Kharif and Rabi were positive and highly significant [10].

3.14 It was also found that farmers in Haryana invested in higher HP pumps when power availability is lower in the main growing seasons of Rabi and Kharif. Moreover, average availability *per se* during a season is not the critical consideration behind HP investment decisions; expectations of power availability during peak periods of demand in these seasons appears to be more influential, which can be explained by the fact that, in the present situation, given the high load on the system during periods of peak demand, disruption of power due to transformer and motor burnouts also occurs most frequently during these peak periods.

3.15 Finally, since the electricity tariff is charged on a per HP basis, it is likely that past tariff rates have influenced HP decisions. The flat rate tariff structure in Haryana was introduced in 1978. To test for the flat tariff rate effect, the rate prevailing prior to the oldest pump purchased by the farmer was taken as an explanatory variable. As expected, the effect of the tariff rate was found to be negative and significant. This suggests that the subsidized tariff rates in the past have encouraged investments in higher HP pumps and that tariff increases are likely to result in lower HP pumps over time.

C. Electricity Tariffs and Farmer Irrigation Costs

3.16 **Electricity Tariff Rates for Agriculture.** The pricing framework for electricity to the agricultural sector is set by the states and thus varies considerably across India. In Haryana, farmers have the choice of a metered rate per unit of consumption or a flat monthly rate per installed HP. Table 3.5 lists the tariff rates under the two systems. At present no charges are levied for getting a connection or for registration, except for reattaching a disconnected line -- a charge of Rs 250 per connection. Farmers opting for metered tariff have to pay Rs 1,000 for a security deposit, a meter service charge of Rs 20 per month and minimum charge of Rs 540/BHP/year.[11] Typically, in areas where a single crop is grown in the year, farmers prefer metered tariffs, but between FY1997 and FY2000, the number of metered connections declined from 89,163 to 69,155. No available data, however, indicates how many meters are actually working in the field. Interestingly, in the Haryana Attitude Survey about 16% farmers reported that although theoretically they have a choice between metered and un-metered connections, the HVPNL field staff does not encourage metered power supply

Table 3.5 - Electricity tariffs for agricultural sector in Haryana and AP

FY2000 Haryana		
Depth of borewell Feet	Metered charges Rs/kWh	Fixed rates per BHP/month
Upto 100	Rs 0.50	Rs 65
101 to 150	Rs 0.38	Rs 50
151 to 200	Rs 0.31	Rs 40
Above 200	Rs 0.23	Rs 30
FY2000 Andhra Pradesh		
HP of pump	Tariff rate/BHP/year	
	DPAP districts[1]	Non - DPAP districts
0-3	Rs 100	Rs 150
>3 - 5 HP	Rs 200	Rs 250
>5 - 10 HP	Rs 300	Rs 350
> 10 HP	Rs 400	Rs 450

Notes: [1]DPAP are drought prone districts. There are 14 such districts in AP: Prakasham, Medak, Anantapur, Adilabad, Khamam, Cudappha, Mehboobnagar, Chittor,Rangareddy, Nalgonda, Nellore, Karimnagar, Kurnool, Srikakulam
Source: Haryana data- HVPNL; Andhra Pradesh data-APTRANSCO

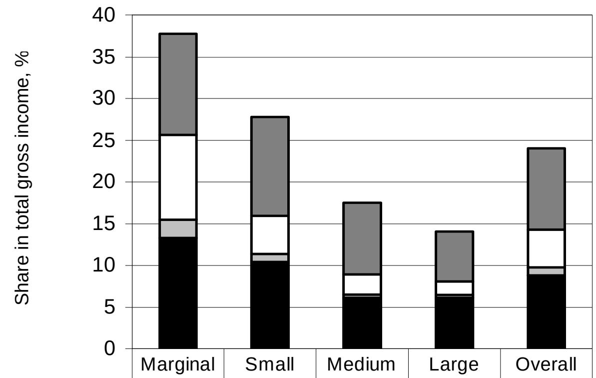
[10] See Haryana Power Supply to Agriculture report for more detailed discussion.
[11] The present system of tariff rate based on depth of water table was introduced through out the state of Haryana in May 1998. A survey was conducted in 1998, and the agriculture connections were classified in each "Patwar" (administrative unit comprising of a few villages) based on the depth of water table. For each Patwar, the groundwater depth slab which recorded the maximum number of pumps, was used to define the depth of water table for that Patwar and the tariff rate was decided accordingly.

for agricultural consumers. This practice may partly explain the increase in the number of flat rate connections from 275,914 to 283,710 during the same period.

3.17 In contrast to Haryana, all farmers in AP pay a flat rate per month for their electricity consumption, rising according to the size of the pump and the region. Districts in AP are classified into drought prone and non-drought prone areas, and the unit rates charged are higher in the latter districts. In FY2000, there were about 2,000,000 agricultural connections in AP.

3.18 **Share of Electricity Tariffs in Gross Farm Incomes of Electric Pump Users.** For the average electric pump owner in Haryana, electricity tariffs account for a small but regressive share of gross farm income 9% for those who own only electric pumps,[12] (Figure 3.5) 2% for electric pump owners using canal water and 1% for farmers with an additional diesel pump. The portion is small, but being regressive, its share in gross farm income decreases as farm size increases. The percentage share of electricity tariffs in gross farm income for marginal farmers who use an electric pump exclusively is 13%, in contrast to 6% for large farmers. The same pattern applies to farmers who use electric pumps and other sources of irrigation water. The percentage share of electricity tariffs for marginal farmers is 5% for electric and canal users and 2.5% for electric and diesel users. For large farmers, it is 1% and 0.8% respectively. As in Haryana, electricity tariffs take a small but regressive share in gross farm income for farmers in Andhra

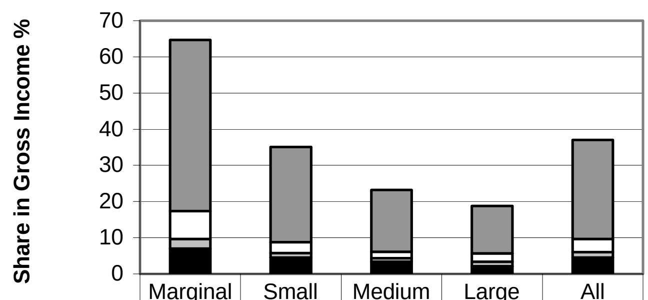
Figure 3.5 - Electric Pumps only: Irrigation Cost as a Percent of Gross Farm Income in Haryana



	Marginal	Small	Medium	Large	Overall
Fixed Cost of Pump and Well/yr,%	12.1	11.9	8.6	6	9.7
Purchase of Water,%	0	0.01	0	0	0
Motor Burnout,%	10.15	4.56	2.39	1.64	4.52
Pump Maintenance ,%	2.22	0.93	0.43	0.37	0.94
Tariff,%	13.27	10.42	6.09	6.08	8.84

Note:Pump maintenance includes travel costs for repair and other costs. Motor burnout out consists of motor rewinding cost. Fixed costs per year cover pump and well investments. Some farmers have zero fixed costs, as pumps are fully depreciated (assuming 20 yrs lifespan).
Source: Haryana Recall Survey.

Figure 3.6 - Electric Pumps only: Irrigation Cost as a Percent of Gross Farm Income in Andhra Pradesh



	Marginal	Small	Medium	Large	All
Fixed Cost	47.3	26.3	17.1	13.1	27.3
Motor Burnout	7.7	3	1.8	2.3	3.7
Pump Maintenance	2.7	1.3	0.9	1.3	1.5
Tariff	7	4.5	3.4	2.1	4.5

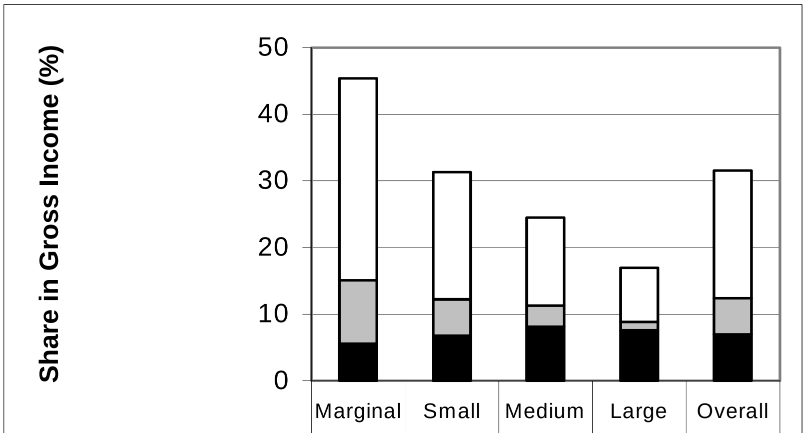
Note:Pump maintenance includes travel costs for repair and other costs.
Motor burnout out consists of motor rewinding cost. Fixed costs per year cover pump and well investments. Some farmers have zero fixed costs, as pumps are fully depreciated (assuming 20 yrs lifespan).
Source: AP Recall Survey.

[12] Gross farm income (or gross value of production) is defined as the sum of the price times the volume of all crops produced during the survey year. The gross farm income does not include proceeds from the sale of crop by-products, non-crop activities (e.g. livestock) and sale of water. Total crop production was taken into account here irrespective of whether it was used for self-consumption, as seed for next year or as marketable surplus. Crop production was valued at the price as reported by farmer for the marketed portion.

Pradesh (see Fig. 3.6). On average, electricity tariffs in AP account for only 4.5% of gross income of electric pump owners, about half as much as in Haryana but again declining as the farm size increases. The share is highest for marginal farmers (7%) and lowest for large ones (2%).

3.19 The flat rate tariff is the main cause of this highly regressive behavior, as is evident when the share of electricity tariff in gross income is compared to the share of diesel costs, where the diesel fuel is paid on per unit basis. For exclusive diesel pump owners, with very little variation as farm size changes, diesel fuel costs account for an average of about 7% of gross farm income in Haryana (Figure 3.7). The regressive nature of the electricity tariff as opposed to diesel rates is due to the flat rate tariff structure of electricity pricing, wherein farmers pay on the basis of installed HP rather than on the basis of per unit consumption (as in the use of diesel pumps). Although marginal farmers have lower installed HP than larger ones, their HP per hectare of gross cultivated area is much higher. This in part explains why share of tariff in gross income is higher for them relative to the larger farmers. The same non-regressive nature of diesel fuel cost could be observed in Andhra Pradesh.

Figure 3.7 - Diesel Pumps only: Irrigation Cost as a Percent of Gross Farm Income in Haryana



	Marginal	Small	Medium	Large	Overall
Fixed Cost	30.3	19.1	13.2	8.1	19.2
Purchase of Water	0	0.02	0	0	0.01
Pump Maintenance	9.49	5.39	3.17	1.28	5.4
Diesel	5.6	6.81	8.13	7.6	6.98

Note: Diesel cost is listed separately and included in total variable irrigation costs.
Source: Haryana Recall Survey.

3.20 **Quality of Power Supply and Motor Rewindings: Motor Rewinding Costs.** Among the costs are those of rewinding pump motors that burn out, an outlay of between Rs 1,000 and Rs 4,000 each time, as pumps do most often and in the largest numbers during the Summer season when total electricity demand, including from non-agricultural sectors, is also highest. Tables 3.6 and 3.7 show the seasonal frequency of pump rewindings in Haryana and AP, respectively. Multiple rewindings are also most frequent in the Summer, when, however, the price of the repair tends to be lowest – Rs 1740 per rewinding compared to Rs 2,180 in the Kharif season. A close examination of these expenses indicated (Table 3.8) that farmers reporting voltage fluctuations incur significantly higher motor rewinding costs with the highest average expenditures on motor rewinding occurring in regions where farmers reported more voltage fluctuations.

Table 3.6 - Frequency Distribution of Rewindings per Pump by Season in Haryana

Season	Number of Pump Rewindings (Percentage Distribution)						Total Number of Pumps
	0	1	2	3	4	5+	
Kharif	69.1	20.2	7.5	2.3	0.6	0.3	897
Summer	68.5	26.1	3.6	0.8	0.6	0.4	720
Rabi	83.9	11.4	3.2	1.5	0.0	0.0	965

Source: Haryana Farmer Recall Survey

Table 3.7 - Frequency Distribution of Rewindings per Pump by Season in Andhra Pradesh

Season	Number of Pump Rewindings (Percentage Distribution)					Total Number of Pumps
	0	1	2	3	4	
Kharif	3.2	79.7	14.4	2.4	0.3	984
Summer		85.7	13.0	1.3		212
Rabi	54.3	27.8	15.5	1.6	0.8	984

Source: Haryana Farmer Recall Survey

Table 3.8 - Expenditures per Rewinding, Rs

Category of Farmers	Summer	Kharif	Rabi
1	355.5	468.7	63.8
2	89.1	29.8	8.2
Average	297.1	437.3	59.9

3.21 **Motor Rewindings and Effective Tariffs Paid.** The indirect costs associated with motor rewindings resulting from the poor quality of electricity supply raise farmers' "effective" per unit costs. The Haryana and Andhra Pradesh studies estimated such effective costs under three different assumptions: 70%, 90% and 100% of the rewinding costs were due to the poor quality of electricity supply.[13] (Table 3.9) For Haryana, under the most conservative (70%) scenario, the effective tariff is estimated to be Rs. 0.81 per kWh, indicating that poor quality of supply raises the per unit tariff paid by farmers by around 23% above the nominal tariff of Rs.0.66 per kWh. On the other hand, if the entire cost of motor rewinding is attributed to poor quality of supply, the effective per unit tariff increases to Rs. 0.88 per kWh or 33% above the nominal rate. In Andhra Pradesh, the effective tariff paid by farmers amounts to Rs.0.34 per kWh under the assumption that 70% of motor rewinding cost is due to poor quality of supply and rises to Rs. 0.40 per kWh under the 100% assumption. These figures, showing the cost savings possible if quality of supply is improved, also indicate how much – with improved quality -- tariff rates can be increased without making farmers any worse off.

Table 3.9 - Per unit tariff paid by farmers under varying assumptions on cost due to poor quality of supply

Region	Number of pumps in sample	Tariff rate Rs./HP/ Year	Estimated consumption metering method (kWh/HP/year) C	Per unit nominal tariff paid (Rs./kWh) N=T/C	Average cost of motor rewinding per HP (Rs./HP) R	Effective cost of electricity under different assumption on cost due to poor quality (Rs./kWh)		
						Incl. 70% of motor rewinding costs	Incl. 90% of motor rewinding costs	Incl. 100% of motor rewinding costs
						E1=(T+0.7*R) /C)	E2=(T+0.9*R) /C)	E3=(T+R) /C)
Haryana								
Crop Year 99-00	532	734	1,116	0.66	244.4	0.81	0.86	0.88
Andhra Pradesh								
Crop Year 99-00	743	206	n.a. (1,100)*	0.19	237.7	0.34	0.38	0.40

Note: Crop year April 1,1999-March 31, 2000

*The estimated consumption of 1,100kWh/HP/year is based on information from utilities (10,222 GWh sales for a connected load of 6,960MWin FY2000) as per Andhra Pradesh, the metering sample results are not available

Source: Haryana and AP Farmer Recall Survey.

[13] For Haryana, the results are based only on the sample of pumps that were metered. The consumption figures are based on the meter readings for these pumps. The tariff rate used is based on average groundwater depth reported at district level. A weighted average of the different districts in each region was taken to estimate the tariff rate at the regional level, with weights proportional to the number of metered pumps in each district in the sample. The average cost of motor rewinding per pump is taken from the farmers' recall data. For AP, the power consumption figures cited are based on the number of hours of pump use as report by electric pump owners in the recall data.

D. Impact of Power Supply Conditions on Net Incomes of Electric Pump Users

3.22 The poor quality of supply has several important effects on farmers beyond the additional expenditures on motor rewindings. An obvious consequence is the lower crop yields caused by the lack of water while motors are repaired/rewound. When these other effects are also taken into account, the cost saving possible due to improvements in quality of supply becomes much larger**.** Using the Haryana survey data, regression analysis isolated the impact of various power supply indicators on the net incomes of electric pump users from other farmer, farm and region specific factors.[14] Several different specifications of the net income regression were tried to test for the robustness of the results

3.23 The study, based on a partial equilibrium framework, found that power supply factors had differing effects on incomes of different groups of Haryana farmers (Table 3.10A-B). The results were found to be quite robust across the different specifications and show that the effect of power supply factors differ significantly amongst farmers belonging to different size categories. The days lost due to transformer burnout during the Kharif, rice-cultivating season have a significant negative effect on net farm incomes of medium and large farmers but not on small and marginal farmers. It is likely that when power is interrupted for a long stretch of time (It took on average around 10 days to rectify a burnt transformer in Kharif-99.), the water shortage results in significant reductions in yields of water intensive crops, such as rice. Conversely, power availability during the two main growing seasons of Kharif and Rabi has a significant positive effect on net incomes of only the marginal and small farmers. This suggests that in the short run, when irrigation capital is held constant, only marginal and small farmers feel constrained by available power supply. Thus the potential for increasing net farm incomes in the short run by increasing availability seems to be limited to only the smaller farmers.

Table 3.10A - Impact of Power Supply Conditions on Short-Run Net Farm Income of Electric Pump Owners-Specification including Technology Variables

Dependent Variable: Net farm Income (in Rs. 1,000)

Variable	Marginal-Small	Medium-Large
Days Lost due to Transformer Burnout (Days/year): Kharif	0.51 (0.44)	-4.60** (-3.84)
Power Availability (hrs/day: Average Rabi-Kharif)	9.47* (1.82)	-1.57 (-0.21)
Unscheduled Powercuts (hrs/day: Average Kharif- Rabi)	5.28 (0.37)	-28.26** (-2.03)
Motor burnout frequency	10.31 (1.43)	1.35 (0.15
Inverse Mills Ratio	146.75** (5.73)	17.19 (0.57)
Number of Observations	86	212

Notes: () t-statistics. * denotes significance at 10% level ** denotes significance at 5% level
Source: Computed.

3.24 Unreliability of power supply has a significant negative effect on net incomes of only the medium and large farmers and only insignificant effects on marginal and small farmers. It is possible that given their limited capacity to bear shocks due to unreliability of supply, small and marginal farmers make precautionary technology choices (larger sized pumps, e.g.) or cropping choices so as to insulate themselves from the vagaries of power supply. Over the long run, improvements in reliability of supply

[14] Net income is defined here as gross value of farm production minus annualized fixed cost and all variable costs (except the imputed cost of family labor and land). Thus this income regression estimates the determinants of net returns to own labor and land. In the regression, the irrigation technology investment is controlled for by including the technology variables total HP and a dummy for investment in supplemental diesel pumps among the explanatory variables. Thus, it estimates the effect of power and other farm and region specific factors on short run incomes (keeping irrigation technology constant).

are likely to lead them to invest in smaller sized pumps and thus increase their long run incomes. This would also have an impact on the pump manufacturing industry in India, which would shift towards more efficient and smaller-sized pumps.

Table 3.10B - Impact of Power Supply Conditions on Short-Run Net Farm Income of Electric Pump Owners- Specification including Gross Cultivated Area

Dependent Variable: Net farm Income (in Rs. 1,000)

Variable	Marginal-Small	Medium-Large
Days Lost due to Transformer Burnout (Days/year): Kharif	0.74 (1.15)	-4.28** (-3.73)
Power Availability (hrs/day: Average Rabi-Kharif)	9.63** (2.38)	-4.86 (-0.67)
Unscheduled Powercuts (hrs/day: Average Kharif- Rabi)	-1.13 (-0.13	-21.94* (-1.64)
Motor burnout frequency	-1.27 (-0.26	-4.10 (-0.48)
Inverse Mills Ratio	71.20** (3.83)	35.27 (1.22)
Number of Observations	134	212

Notes: () t-statistics. * denotes significance at 10% level ** denotes significance at 5% level
Source: Computed.

3.25 Measured by the frequency of motor burnouts, poor quality of supply showed no significant effect for any of the size categories. Field investigators have observed that in areas where motor burnouts are frequent – generally, where water use is intensive and supply quality is poor, motor repair mechanics kept some old motors for use as rolling stock to rent out as stop gaps when farmers' motors burn out. This back-up expedient ensures that farmers do not suffer significant crop loss due to lack of water and incur only the additional out-of-pocket cost of the rentals.

E. Cost and Returns of Different Technology Options

3.26 **Gross Farm Income.** Electric pump owners in the Haryana study had the highest average annual gross incomes (about Rs. 125,000) -- defined as the sum of the price times the volume of all crops produced during the survey year [15]. Diesel pump users came second at Rs.91,000), and water purchasers and rainfed were the lowest on average at Rs.26,000 and Rs.27,000 respectively. Canal users fell in the middle at Rs. 76,000 (Table 3.11). Among electric and diesel pump owners, those who had access to supplemental water, through diesel pumps or canal, also had higher gross incomes than those dependent on electric or diesel pumps alone. It is interesting to note that the average gross income of marginal farmers who own electric pumps is almost three times that of their counterparts in the rainfed and water purchasers category. In particular, the gross income of marginal farmers owning both electric and diesel pumps is almost 6 times that of the rainfed marginal farmers, in part because pump ownership allows even those with very small landholdings to lease in more land and thus increase their scale of operation.

Table 3.11 - Average Annual Gross Income by Farm Size in Haryana, Rupees

Farm size owned	Electric pump owners				Non-electric diesel pump owners			Canal users	Water purchasers	Rainfed	Total
	Electric only	Electric and canal	Electric and diesel	Total	Diesel only	Diesel and canal	Total				
Marginal	36,460	41,920	94,010	46,800	28,000	51,240	30,420	21,000	13,810	15,420	25,880
Small	40,520	72,800	65,080	45,980	41,970	66,360	46,840	70,020	30,850	36,680	49,340
Medium	110,480	90,540	111,070	109,520	93,000	147,540	110,480	122,270	69,060	67,770	108,290
Large	240,490	251,250	286,380	259,960	151,970	250,760	211,250	174,820	129,270	110,000	241,360
Overall	102,000	160,550	161,910	124,090	64,460	157,400	90,780	76,250	25,800	27,290	90,940

Source: Haryana farmers' recall survey.

[15] The gross farm income does not include proceeds from the sale of crop by-products, non-crop activities (e.g. livestock) and sale of water. Total crop production was taken into account here irrespective of whether it was used for self-consumption, as seed for next year or as marketable surplus. Crop production was valued at the price as reported by farmer for the marketed portion.

3.27 In Andhra Pradesh, electric pump owners also had the highest average annual gross incomes at about Rs.112,000, followed by diesel pump users at Rs.91,000. Water purchasers and rainfed farmers were at the other end of the scale with canal users in the middle at about Rs. 54,000 (Table 3.12). On average, the gross income of electric pump owners was almost thrice that of their counterparts in the rainfed and water purchasers category.

Table 3.12 - Average Annual Gross Income by Farm Size in Andhra Pradesh, Rupees

Farm size owned	Electric	Diesel	Canal	Water Purchaser	Rainfed	Total
Marginal	39,420	34,110	17,300	25,070	19,700	27,660
Small	78,630	66,510	43,180	49,190	40,300	63,740
Medium	153,780	153,070	97,240	58,900	55,930	132,770
Large	285,500	197,900	198,650		158,670	247,710
Overall	111,900	91,170	53,770	34,420	38,120	80,810

Source: Andhra Pradesh farmers' recall survey.

3.28 Access to irrigation is likely to increase returns per unit of cultivated land by raising the yields of many crops (particularly water-intensive ones), keeping everything else constant, and by helping to reduce some of the risks associated with variation in rainfall. Irrigation also enables more intensive cultivation through multiple cropping. To assess the gross returns per unit of cultivated land across irrigation technologies, the above values were normalized to a per hectare basis so that average per hectare annual gross farm income could be calculated for alternative sources of water in Haryana[16] (Table 3.13).

Table 3.13 - Gross Farm Income per hectare of Net Cultivated Area in Haryana, Rs./ha

Region/ farm size category	Electric pump owners				Non-electric diesel pump owners			Canal users	Water purchasers	Rainfed	Total
	Electric only	Electric and canal	Electric and diesel	Total	Diesel only	Diesel and canal	Total				
Marginal	29,750	27,960	42,220	31,940	34,250	35,430	34,370	30,580	26,020	27,480	29,500
Small	24,950	27,400	25,650	25,170	27,130	41,260	29,960	51,950	22,870	27,270	31,980
Medium	33,120	26,210	30,470	31,710	30,830	37,650	33,020	41,140	29,690	28,340	33,120
Large	27,100	24,360	30,030	27,940	28,250	35,960	32,870	33,770	18,770	27,230	29,010
Overall	29,200	25,600	31,040	29,530	30,330	37,660	32,400	40,160	25,650	27,570	31,070

Source: Haryana farmers' recall survey

The results show that farmers with direct access to irrigation either through electric or diesel pumps or canal water display higher gross incomes per hectare of net cultivated area than rainfed farmers or those who relied solely on purchased water. Non pump canal users and those who used diesel pumps with canal posted the highest gross incomes per ha. In Andha Pradesh, diesel pump owners on average had the highest gross returns per unit of net cultivated area, followed by electric pump owners and water purchasers (Table 3.14). These findings, however, are not adjusted for agro-climatic conditions affecting yields, farmer specific socio-economic characteristics, availability and quality of infrastructure and services, including electricity, and other variables that could influence income levels.

Table 3.14 - Gross Farm Income per hectare of Net Cultivated Area in Andhra Pradesh, Rs./ha

Farm size owned	Electric	Diesel	Canal	Water Purchaser	Rainfed	Total
Marginal	38,400	58,690	28,620	43,730	25,160	37,030
Small	48,000	53,490	31,240	39,540	30,690	42,970
Medium	57,030	58,570	35,890	45,510	32,380	51,080
Large	56,640	39,320	30,330		25,180	46,950
Overall	49,560	56,030	31,200	42,670	28,210	43,340

Source: Haryana farmers' recall survey.

[16] Net cultivated area is the maximum area cultivated by a farmer in any season. Normalization by net cultivated area as opposed to gross cultivated area helps to capture the returns associated with multiple cropping.

3.29 **Production Costs under Different Technologies.** To compare farm production costs by technology type, total costs were aggregated into four major categories: hired labor, own labor, materials and irrigation costs and examined relative to gross income. In Haryana, all types of electric and diesel pump owners on average tend to use various materials (fertilizers, pesticides, farm cultivation services such as tractors and animal draft, non-irrigation diesel, etc) more intensively than the canal, water purchasers and rainfed farmers (Table 3.15). On average, these costs account for about 20-22% of gross income for pump owners, compared to about 15-16% of non-pump owners. The cost of irrigation, as a share of gross income, is the highest for the pure electric pump owners and the pure diesel pump owners (around 25% to 31%)[17]. Access to complementary sources of water, especially canal, reduces the share taken by irrigation costs by 8 to 12 percentage points. Water purchasers, with the percentage share of irrigation costs at 9%, have the next highest share of irrigation costs after the pump owners. The irrigation cost share for pure canal users, at about 0.5% is significantly lower than all other sources of irrigation, an indication of the large disparity between the cost of irrigation using canal and relying on privately owned pumps.

[17] The decomposition of irrigation costs into fixed and variable costs is explained in greater detail in the next subsection.

Table 3.15 - Production Cost as Percent of Gross Income in Haryana

Region/ farm size category	Hired Labor	Own Labor*	Materials	Irrigation Cost			Total Cost
				Variable Costs	Annualized Fixed Cost of Pump and Well	Total	
1. Electric pump users only							
Marginal	8.81	13.08	21.97	25.74	12.1	38.4	82.4
Small	7.20	10.43	22.53	16.07	11.9	28.7	68.7
Medium	6.33	5.90	21.06	9.08	8.6	18.3	51.7
Large	8.03	5.39	23.97	8.17	6	14.9	53.7
Overall	7.43	8.52	22.19	14.54	9.7	24.9	63.5
2.Electric and Canal users							
Marginal	10.72	7.06	19.44	8.38	3.6	12.2	49.2
Small	6.21	9.44	19.68	5.46	8.3	13.8	49.1
Medium	6.7	4.65	19.47	9.71	7.6	17.3	48.1
Large	7.13	5.26	21.55	5.53	3.1	8.8	40
Overall	7.02	5.71	20.46	7.15	5.4	12.7	44.6
3. Electric &Diesel pump users							
Marginal	6.29	6.55	20.1	11.06	3.9	15.7	48.4
Small	7.81	7	19.56	12.24	10.3	23.6	58.4
Medium	5.73	5.17	19.42	9.26	8.6	18	48.3
Large	6.75	4.32	19.81	6.2	5.8	12.4	43.5
Overall	6.33	5.22	19.63	8.71	7.4	16.5	47.8
4. Diesel pump users only							
Marginal	7.70	6.83	21.82	14.96	30.3	45.2	81.6
Small	10.10	6.68	20.34	12.22	19.1	31.3	68.4
Medium	12.69	8.16	24.46	10.99	13.2	24.2	69.5
Large	13.53	7.00	21.36	8.34	8.1	16.5	58.3
Overall	10.60	7.23	22.17	12.21	19.2	31.4	71.4
5. Diesel and Canal users							
Marginal	6.19	7.82	21.41	13.51	17.9	31.4	66.8
Small	9.09	5.99	20.24	12.24	14.2	26.5	61.8
Medium	11.50	7.41	22.03	9.22	8.4	17.6	58.6
Large	14.50	8.00	22.59	10.38	4.1	14.4	59.5
Overall	11.58	7.35	21.80	10.55	8.9	19.5	60.2
6. Canal users only							
Marginal	4.58	5.43	17.08	0.47		0.47	27.56
Small	5.47	4.94	14.29	0.42		0.42	25.13
Medium	6.27	5.98	15.63	0.51		0.51	28.39
Large	5.75	5.33	17.82	0.48		0.48	29.39
Overall	5.40	5.42	15.91	0.46		0.46	27.20
7. Water Purchasers							
Marginal	5.87	11.48	14.90	10.44		10.44	42.69
Small	10.00	11.12	20.26	8.76		8.76	50.15
Medium	8.54	8.35	14.36	4.16		4.16	35.41
Large	6.68	7.42	36.59	12.42		12.42	63.11
Overall	6.97	10.97	16.37	9.48		9.48	43.79
8. Rainfed							
Marginal	7.67	11.40	15.01				34.07
Small	10.26	6.09	15.75				32.10
Medium	7.63	5.86	16.31				29.80
Large	13.08	5.42	17.99				36.49
Overall	8.13	9.72	15.34				33.20

Notes: * Imputed at village level wages for male and female labor. Material costs include fertilizers, pesticides, etc.

3.30 Among both electric and diesel pump owners, the share of irrigation cost in gross income tends to increase as farm size decreases. But the degree of disparity between marginal and large farmers varies considerably by technology. It is only about 3 percentage points for electric with canal and electric with diesel pump owners, but the difference is 23 percentage points for electric pump owners only. The difference is 17 to 29 percentage points for farmers who use only diesel pumps and use diesel with canal. The gaps in cost shares imply that small and marginal farmers, especially those dependent on electric pumps only and diesel pumps, would tend to be more vulnerable to increases in irrigation costs. Since their total cost of production as a share of gross income is already much higher than that of larger farmers, further increases in irrigation costs would gravely affect their viability as farmers.

3.31 In Andhra Pradesh, the results suggest that irrigation costs are the largest component of costs for pump owners, accounting for about 36% of gross income for owners of electric pumps and 48% for diesel pump owners[18] (Table 3.16). On the other hand, irrigation costs are much lower, accounting for less than 11% of gross income, for farmers without pumps. For them, the cost of other materials (such as fertilizers, pesticides, farm cultivation services like tractors and animal draft, non-irrigation diesel, etc) is the most important component of cost. On average, hired labor costs account for less than 8% of gross income for all categories except diesel pump owners (13%).

Table 3.16 - Production Cost as Percent of Gross Income in Andhra Pradesh

Region/ farm size category	Hired Labor	Materials	Irrigation Cost		
			Variable Costs	Annualized Fixed Cost of Pump and Well	Total
1. Electric pump owners					
Marginal	1.8	27.7	17	47.1	64.1
Small	1.9	25.6	8.6	26.1	34.7
Medium	2.8	23.3	5.9	16.9	22.8
Large	4.1	20.7	5.3	12.6	17.9
Overall	2.4	24.9	9.4	26.9	36.3
2. Diesel pump owners					
Marginal	9.3	32.4	13	65.1	78.1
Small	22.1	34.8	11.3	35.5	46.8
Medium	8.4	27.9	7.7	16.5	24.1
Large	17.6	28.7	7.6	10.4	18.1
Overall	13.2	31.4	10.5	37.7	48.2
3. Canal users					
Marginal	11.4	66.6	4.1	n.a[1].	4.1
Small	6.7	65.0	4	n.a[1].	4
Medium	4.5	62.4	5.2	n.a[1]	5.2
Large	2.6	45.9	3.8	n.a[1]	3.8
Overall	8.1	64.0	4.3	n.a[1]	4.3
4. Water Purchasers					
Marginal	6.8	47.6	11.1	0	11.1
Small	6.1	47.2	12.4	0	12.4
Medium	3.1	29.9	7.4	0	7.4
Large					
Overall	6.3	46.2	11.2	0	11.2
5. Rainfed					
Marginal	5.5	40.1	0	0	0
Small	6.9	43	0	0	0
Medium	5.4	49.5	0	0	0
Large	8.7	46	0	0	0
Overall	6	43	0	0	0

Notes: * Imputed at village level wages for male and female labor. Material costs include fertilizers, pesticides, etc.
[1]In general canal users do not pay for the fixed costs of canal construction and maintenance. However in some minor irrigation schemes, canal users are now paying about 15% of rehabilitation costs. Data on these costs was not collected during the survey.

F. Net Incomes under Different Technologies

3.32 Electric pump owners tend to have higher incomes than the other types of farmers. Among the different irrigation technology users in Haryana, net farm income on average was highest for electric pump owners with access to either canal or diesel, and diesel owners with access to canal came second. Interestingly, the net income of exclusive electric pump owners was found to be almost the same as that of the non-pump canal users. The lower net income of exclusive diesel pump owners was found to be almost half that of the exclusive electric pump owners. As expected, the net incomes of rainfed and water

[18] Since the sample of electric pump owners who use canal and/or diesel pumps conjunctively is rather small, production could not be separately estimated for these categories. Similarly for diesel pump owners who use canal conjunctively.

purchasers were the lowest. The net income of the electric pump owners as a whole was found to be almost 1.5 times that of diesel pump owners, 1.2 times that of non-pump canal users, 4 times that of the rainfed farmers and 4.2 times that of the water purchasers (Table 3.17).

Table 3.17 - Annual net farm income per farm in Haryana

Region/ farm size category	Electric pump owners				Non-electric diesel pump owners			Canal users	Water purchasers	Rainfed	Total
	Electric only	Electric and canal	Electric and diesel	Total	Diesel only	Diesel and canal	Total				
Marginal	21,720	23,390	67,480	28,830	13,450	28,630	15,030	17,290	9,730	11,980	16,820
Small	22,670	48,110	36,800	26,120	20,240	38,430	23,880	60,570	20,750	27,100	32,980
Medium	68,120	52,960	67,330	66,860	54,130	101,900	69,440	103,150	52,530	51,760	71,600
Large	158,620	174,700	194,820	175,410	78,210	146,400	119,130	144,970	93,080	75,820	160,970
Overall	62,700	105,930	105,960	78,960	34,540	97,880	52,480	64,410	18,460	20,730	59,540

Source: Farmers' recall data

3.33 Some districts in AP were affected by drought during the survey year. With the data available at this stage, it is not possible to assess the exact magnitude of drought-related production losses, but it is highly likely that the tables on costs and returns presented in the previous sections, may not be representative of an average year. Thus this section presents some of the important costs and returns tables just for the non-drought areas and compared with the tables presented in earlier sections, which covered the entire state. The drought-affected districts -- Nellore, Cuddapah, Mahabubnagar, Medak and Nalgonda – are those that received less than 70% of average annual rainfall during the survey year and have been excluded from the computations in Table 3.18 of gross income, net income and irrigation costs in the non-drought areas [19]. On average across technology groups, gross and net incomes are about 8% higher when drought areas are excluded, and the incomes of electric pump owners show a much steeper increase (around 14%) than other technology groups when drought areas are excluded. Within the category of electric pump owners, the net incomes of marginal farmers show the highest increase -- around 20% when drought areas are excluded.

Table 3.18: Costs and Income in Non-Drought Areas
(Figures in parenthesis give percentage difference between excluding and including drought areas)

	Electric	Diesel	Canal	Water Purchaser	Rainfed	Total
Gross income(Rs.)	127,630 (14.1)	94,590 (3.8)	57,020 (6.1)	36,790 (6.9)	38,740 (1.6)	87,020 (7.7)
Net income (Rs.)	100,730 (14.3)	66,210 (3.8)	33,560 (7.2)	24,250 (8.9)	28,490 (1.2)	64,350 (8.5)
Irrigation costs as % of gross income (excluding drought areas)	32.1	44.6	4.2	9.5	0	21.4
Irrigation costs as % of gross income (not excluding drought areas)	36.3	48.2	4.3	11.2	0	24.4

Source: AP Farmer recall data

3.34 Irrigation costs account for about 21% of gross income in non-drought areas as opposed to 24% in the state as a whole. For electric pump owners, irrigation costs constitute about 32% of gross income

[19] Detailed tables on costs and income after excluding the drought-affected areas are given in annex.

in non-drought areas and 6% in the entire state. For marginal and small electric pump owners, irrigation costs account for about 60% and 32% of gross income, respectively, in non-drought areas -- as compared to 64% and 35% in the state as a whole. The share of electricity tariffs in gross income shows hardly any difference whether drought areas are included or excluded. Electricity tariffs that account for about 4% of gross income of the average electric pump owner are, as noted earlier, highly regressive in relation to farm size, accounting for 6.4% of gross income for marginal farmers but only 2% of gross income of large farmers.

CHAPTER 4

CONCLUSIONS AND POLICY RECOMMENDATIONS

A. Farmer Willingness to Pay for Improved Quality

4.1 To this point, the paper has focused on the need for improvements in the quality of electricity services to farmers, and the associated potential benefits. It has shown that these benefits and the costs borne by these farmers in the form of better quality and higher tariffs can be brought into balance. A basic support of that argument is the finding that farmers appear willing to pay for improved supply of power.

4.2 The study in Haryana finds farmers' willingness to pay for improved availability quite high, especially among small and marginal farmers. The econometric analysis based on the results of the recall surveys provides estimates of a farmer's willingness to pay (WTP) [20] for different power supply indicators. Since several different specifications of net income regression were tried, a range of WTP estimates are reported. According to those estimates, marginal and small farmers are willing to pay between Rs.9,400 to Rs. 9,700 for an additional hour/per day increase in availability of power (Table 4.1) in the short run, which is defined as the time period over which irrigation technology used remains constant. However, medium and large farmers seem to have a zero valuation for power availability at the margin, indicating that, given their technology choices, available power supply does not currently constrain them and greater availability is not likely to have any short run effects on their net farm incomes.[21] This result has major implications on efficiency of resource use, because it implies that important resources like water and power have a zero marginal valuation in the short run for around 60% of the electric pump owning population in Haryana. To improve conservation of these scarce resources, it is imperative to shift to energy metering and per unit tariffs.

4.3 While the willingness among medium and large farmers to pay for improvements in reliability (rather than availability) of power supply is quite high in the short run, small and marginal farmers attach no significance to improving reliability in the short-run. In the medium run, however, given the time to adjust irrigation technology choices, the effect is quite large. Small and marginal farmers have over-invested in electric HP as a way to cope with the unreliability of supply. Should reliability improve, these farmers would be expected to shift over time to lower HP pumps and thus lower their costs. The willingness to pay for reduction in days lost due to transformer burnouts is also quite high for medium and large farmers, suggesting that, in general, farmers value improvements in reliability and quality much more than increases in availability.

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[20] If Y is the short run net farm income and I is a power supply indicator , then marginal willingness to pay (MWTP) is defined as MWTP $= \partial Y/\partial I$. It is also assumed that everything else in the farm economy, such as output/ input prices and the overall regulatory framework, remains constant. Thus these effects can be regarded as partial equilibrium effects. An important advantage of the partial equilibrium approach is its empirical simplicity and also the fact that the first round effects are, in general, an acceptable first-order approximation of the total effects (Sadoulet and deJanvry). However, it is important to keep in mind that the partial equilibrium analysis does not take into account several important effects such as the income and cost changes that might shift the demand and supply curves and the interaction across markets with products or factors that are close substitutes or complements in consumption or production. For example, it is likely that policy reforms would affect agricultural production and hence lead to a change in the prices of major crops produced in the states. These price changes are not taken into account in the calculation of first round effects here.

[21] In the long run, however, when irrigation capital has adjusted to this higher level of availability, net incomes are likely to increase significantly for all size categories due to the reduced demand for total HP and other costly back up strategies such as supplemental diesel pumps. In addition, larger potential gains from improved availability are likely to occur when accompanied by improvement in marketing conditions, as explained elsewhere in the report in greater detail.

Table 4.1 - Farmer Willingness to Pay (Rs.) for Improvement in Power Supply Indicators: Short and Medium Term in Haryana

Reform Scenario	Medium: By Farm Size Category			Short Term: By Farm Size Category		
	Marginal -Small	Medium-Large	Average	Marginal-Small	Medium-Large	Average
Base year incomes	33,400	119,000	94,500	33,400	119,000	94,500
Increase in power availability-by 1 hour per day for the year	14,000-14,200	ns	4,000-4100	9,400-9,700	Ns	2,500-2,800
25% Improvement in reliability	8600-8700	14,900-19,400	13,100-16,300	ns	14,900-19,400	10,600-13,800
25% Decrease in days lost due to transformer burnout-	ns	10,900-11,800	7,800-8,400	ns	10,900-11,800	7,800-8,400
25% Decrease in Frequency of motor-burnouts	244	462	399	244	462	382

Notes: n.s.: effect not significant from zero in net income regression. Short run is defined as the time period over which Irrigation technology used remains constant. Medium run is defined as the time period over which irrigation technologies are allowed to change.

B. Power Sector Reform: Its Impact on Farmers

4.4 Will power sector reform be a boon or a bane to farmers? Higher agricultural tariffs would be critical to ensure the utilities' financial health and raise the resources needed to improve power supply to rural areas. In developing an action plan, the appropriate sequencing of various reforms would be crucial, as the pace and combination of actions would have differing impacts on farmers. To gain a better understanding of what the potential impact of different reform packages will be on farmers, three different policy reform scenarios were simulated: No reform (Scenario I), Slow reform (Scenario II) and Accelerated reform (Scenario III) scenarios. The assumptions under these different scenarios are summarized in Table 4.2.

Table 4.2 - Policy Reform Simulations: Assumptions under Different Scenarios

Year	Tariff Increase %			Change in Availability Hrs			Change in Reliability %			Transformer Burnout: Days Lost %			Frequency of Motor Burnout %		
	Scenario			Scenario			Scenario			Scenario			Scenario		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Base	Rs 4,649			8 hrs/day			2.7 hr powercut/day			10.1 days lost			1 burnout/yr		
1	+50	+50	+50	0	0	0	0	0	0	0	0	0	0	0	0
2	+20	+35	+35	0	+1	+1	-5	0	+25	-5	0	+25	-5	0	+25
3	+10	+35	+35	0	+1	+1	-10	+5	+20	-10	+5	+25	-10	+5	+20
4	+25	+35	+35	0	+1	+2	-15	+10	+20	-15	+10	+25+	-15	+10	+20
5	+15	+35	+35	0	+1	+2	-20	+15	+20	-20	+15	+25	-20	+15	+20
6	+10	+15	+15	0	+1	+2	-25	+20	+15	-25	+20	+20	-25	+20	+15

Note: Scenario 1: No reform. Scenario II: Slow Reform. Scenario III: Accelerated Reform.

4.5 The simulations show that matching agricultural tariff increases with improvements in quality would actually benefit farmers. At a slow reform pace (Scenario II), incorporating improvements in availability, increased speed in transformer repair and improvements in quality of power supply so that motor burnouts are fewer, farm incomes of small and marginal farmers are expected to increase by 47% to 48% in the medium term (6 years), with a (phased) 473% increase in agricultural tariffs (Table 4.3). Farm incomes of medium and large farmers will also increase by 12% to 18%. Under a more accelerated reform scenario[22] with the same phased 473% increase in agricultural tariffs but a more rapid improvements in power supply over 6 years (Scenario III), farm incomes of small and marginal farmers increase significantly by 100% to 121%, while incomes of medium and large farmers increase by about 37% to 48%. Increasing agricultural tariffs[23] (while allowing power supply conditions to continue to deteriorate (Scenario 1) would be so detrimental that the income of medium and large farmers would decline by 46% to 55% while small and marginal farmers would find the use of electric pumps no longer sustainable.

Table 4.3 - Policy Reform Simulations: Medium Term Impact of Power Reform on Farmer Incomes Different Farm Size Categories at the end of 6 years

	Scenario I: No reforms		Scenario II: Delayed reforms				Scenario III: Accelerated reforms	
			With aggressive tariff increase		With gradual tariff increase			
	Marginal and Small	Medium and Large	Marginal and Small	Medium and Large	Marginal and Small	Medium and Large	Marginal and Small	Medium and Large
Base year income (Rs.)	33,400	119,000	33,400	119,000	33,400	119,000	33,400	119,000
Base year tariff (Rs.)	2,410	5,650	2,410	5,650	2,410	5,650	2,410	5,650
Post reform tariff (Rs.)	7,560	17,700	34,640	81,120	13,830	32,380	13,830	32,380
(% change)	(213%)		(1335%)		(473%)		(473%)	
Post reform availability (% change)	8.1 hours/day (0%)		9 hours/day (11%)		9 hours/day (11%)		10 hours/day (23%)	
Post reform reliability (% change)	5.2 hours/day (99%)		1.5 hours/day (-42%)		1.5 hours/day (-42%)		0.9 hours/day (-67%)	
Post reform days lost due to transformer burnout in kharif season (% change)	19.3 days (99%)		5.6 days (-42%)		5.6 days (-42%)		3.3 days (-66%)	
Post-reform frequency of motor burnouts/year (% change)	2 (99%)s		0.6 (-42%)		0.6 (-42%)		0.33 (-67%)	
Percentage change in real net farm income over base year	Use of electric pumps no longer sustainable	-46 to –55%	-2 to –3%	-14 to –20%	47 to 48%	12 to 18%	100 to 121%	37 to 48%

C. Options for Power Reform

4.6 India and its several states have generally accepted the need for reform of the power sector, both to improve service and insure cost recovery. To translate that acceptance into action, however, it is necessary to adopt a strategy that defines the scope and sequencing of reform measures. The goal is to enable utilities to perform at high levels of efficiency, satisfying the expectations of farmers and rewarding their higher payments for electricity with power supply of the requisite quality. To achieve these multiple goals, policymakers may choose among three possible options:

[22] The improvement in the quality of power supply achieved under the two reform scenarios, are expected to be derived not only from new physical investments to improve the power distribution infrastructure, but also by institutional changes bringing greater customer service orientation by utilities staff, efficiency in service delivery (e.g., time required to repair transformers) and increased transparency and accountability of operations to reduce theft, commitment to collection of arrears, etc..

[23] Increases in agricultural tariffs would be necessary since further cross-subsidies from industry would certainly be impossible: industries would fly away from the grid. And, politically, it would certainly be difficult, if not impossible, to increase dramatically tariffs to domestic consumers.

- A gradual approach putting improvements in service ahead of tariff adjustments. This would be a long process. Some agricultural tariff increases will still take place because of the financial constraints and the limits to which the agricultural sector could be cross-subsidized by other sectors (i.e., industry and commercial consumers). Alternatively, substantial resources would need to come from other sources to continue to subsidize farmers and to finance the initial investments required to improve quality.

- An aggressive approach making efficiency improvements and tariff increases in parallel and at a rapid pace. This would likely require initial increases in agricultural tariffs to start improving the financial condition of the utilities and facilitate privatization of distribution, even before the improvements in quality of services are perceptible. Progress will not be uniform in all parts of the state but the dynamics would maximize the chances of success over the state.

- A selective geographic approach with efficiency improvements and tariff increases closely associated and implemented in specific areas of the state -- district by district or region by region -- so that tariff adjustments and improvements in the quality of power come more or less simultaneously in the selected locales (for example through linking tariffs to the quality of power). By "zoning" consumers among a number of providers, this option would produce significant differences in tariffs reflecting differences in power quality and potentially resulting in varying rates of long-term progress in service performance at separate locations. The political and technical feasibility of such an option remains uncertain.

4.7 Whatever option is retained by the state government, two basic measures remain essential:

- ***Communication and Consumer Awareness***. Fostering an increased awareness and understanding among policy makers and the general public of the current situation in the power sector is vital to achieving broad-based consensus and support for reform. In addition to publicizing to stakeholders the poor operational performance of the utilities and the potential benefits of reform, the campaign should highlight the level of theft and pilferage ("half of the power generated is not paid for") and its broader impact on the quality of power supply.

- ***Metering.*** This would be a "win-win" option, essential for reducing theft, facilitating end-use efficiency improvements, and implementing appropriate pricing policies (e.g. eliminating the regressive impact of flat-rate tariffs) by increasing transparency on the consumption levels of various types of consumers. Metering all consumers will help determine the exact consumption of power by farmers and the extent of true subsidies.

A summary of the recommendations is presented in a matrix form in Table 4.5.

D. An Integrated Approach to Efficiency

4.8 Several studies indicate that substantial energy savings can be achieved by replacing existing inefficient pumpsets with more energy efficient ones[24]. Box 4.1 details the findings of field studies in Haryana.

[24] See for e.g.(NABARD, 1984), (Patel and Pandey, 1993),(Jain, 1994), (Boothra and Bajaj, 1994), (3EC,1998). .

Box 4.1 - Efficiency Opportunities in Agricultural Pumpsets

In Haryana, a detailed survey of pumpset efficiency in four feeders revealed that the average efficiency levels are in the range of 21-24%, well below technical and economic potential. About one fourth of the pumps surveyed had efficiency below 20%, about one half of the pumps were in the 20-10% range, and the remaining fourth had pump use efficiency over 30%. Only 2% of the pumps surveyed had efficiency levels above 40%*

Pumpset rectification has traditionally involved replacing foot valve and suction and delivery piping to reduce frictional losses and increase water delivery potential. The benefit to the utility would materialize only if the pumpset is replaced by a lower-rated but more efficient pumpset. When implemented with resized motors, the same amount of water can be delivered for significantly lower energy consumption.

Field studies in Haryana on four 11kV feeders (Bastara, Alampur, Handikera, Gujjarwas) indicate that the replacement of pumpsets should be implemented in conjunction with the rehabilitation of the distribution system to maximize energy savings. These studies indicate that overall system efficiency of upto 50% are easily is achievable. The rehabilitation of the agricultural feeders will improve power quality supplied to the pumpsets to enable them to operate more efficiently, reduce burnouts and thus extend their operational life.

*DSM Feasibility study in Handikhera and Gujjarwas 11 kV feeders (3EC, 2000) and DSM feasibility study in Bastara and Alampur feeders (3EC, 1998). Data from efficiency

4.9 More efficient pumpsets could reduce electricity consumption by 30-45% (Table 4.4) and therefore limit the impact that tariff adjustments would have on the cost of farming operations and farmers' incomes. Although such pumpsets costs about 30% more than the standard variety, the burden is one farmers and utilities are likely to share, and, it has been estimated that in Haryana, the farmer's investment should pay for itself in lower electricity costs and less frequent burnouts with about a years.

Table 4.4 - Energy savings from implementing comprehensive pumpset replacement program

Step	Measure	Energy Conservation Potential
1	Replacement of GI suction pipe and GI foot valve with low friction RPVC pipes and valve.	20%-25%
2	Replacement of suction pipe, foot valve, and delivery pipes.	30%-35%
3	Replacement of suction and delivery pipes, foot valve, and pump with properly sized energy efficient mono-block pump.	40%-45%

4.10 Matching system rehabilitation and the operational efficiency gains it would bring to the utilities with a cost- and power-saving move by farmers to more efficient pumps promises significant benefits to all. Realizing them, however, depends on rehabilitation actually raising power supply quality. Otherwise, the better pumps will burn out as often as the lower-grade ones. It is also important to note that, for initiatives to promote demand-side management (DSM) and energy efficiency improvements to succeed, new institutional and incentive systems are also required. The flat-rate system, the low tariffs and the total lack of utility staff motivation to improve the quality of service now doom any outreach effort to skeptical consumers. Such programs also require significant management, customer relations and marketing skills, load research, program monitoring and evaluation skills etc., none of which is readily available within utilities today. Though adequate technical skills are available, considerable DSM capacity-building efforts would be required to make energy efficiency improvement feasible. Box 4.2 presents a summary of the experience in end-use efficiency in Andhra Pradesh.

Box 4.2 -Agricultural DSM Experience in Andhra Pradesh

In early 1990s, Andhra Pradesh recognized the potential benefits of introducing end use efficiency for agricultural. The requirement of a steady quality power supply as prerequisite was also appreciated. The state pioneered the concept of integrated energy efficiency in India by introducing High Voltage Distribution System (HVDS) to improve the quality of power supply to agricultural consumers along with replacement of existing inefficient pumps with higher efficiency and lower capacity pumps to reduce energy consumption for the same water delivery. Under this plan, existing three phase Low Voltage Distribution System (LVDS) was to be converted as single phase HVDS as close to consumer as possible. Small capacity single phase transformers (10 or 15 KVA) were to be installed to supply a group of few consumers and the existing three phase pumpsets were to be replaced with energy efficient single phase models.

A technology demonstration involving 7,200 pumpsets was undertaken in Warangal district with the support from the Japanese OECF (now JBIC). The response from consumers to this forced conversion program was mixed and only about 2,010 pumpsets were replaced by efficient single-phase models. A similar demonstration was attempted with the support from UK DfID in Nalgonda district involving 3,200 pumpsets connected to one 33/11 kV substation. Losses were brought down to about 2-2.5% in the LT section. However, only about 850 consumers participated in the demonstration project. The less than adequate response from farmers is attributable to a combination of factors including the resistance to change by unauthorised consumers, use of higher than required or declared horsepower etc. Other issues faced during the implementation of these programs included farmers' apprehension of the single phase system, some problems with contractor for the repair and maintenance of the new pumpsets, APTRANSCO/DISCOM's inability to roster and manage agricultural consumption in these areas, interference from local mechanics whose livelihood was affected by the contractor implemented pumpset program etc.

Learning from this experience, Andhra Pradesh is now adapting a modified approach in the AP Integrated Agricultural Energy Efficiency Pilot project funded through a US$ 4.6 million grant by the Government of Norway under its Activities Implemented Jointly (AIJ) Program. This pilot covers approximately 5,800 pumpsets connected to two 33/11 kV substations in Chittoor and Karim Nagar districts. Under this pilot project, HVDS will be developed in a three phase configuration, to eliminate one of the main concerns of farmers for participating in the program.

An outreach program explaining the benefits of the new distribution system and a voluntary efficient pumpset scheme will be offered to farmers in close coordination with local groups/banks involved in outreach activities for other agricultural and rural development initiatives. On an average, it is expected that the end-use efficiency will go up from about 25% to about 50%. This pilot is in early stages of implementation and is expected to be completed by December 2002.

E. Complementary Measures

4.11 Reform should encompass a range of measures having to do with power specifically and agriculture broadly. Some of the latter are vital investments in improving the rural economy – on- and off-farm – and have been detailed in a number of World Bank studies on agriculture in South Asia. Their importance to power-supply reform lies in their contribution to farmers' ability to pay for higher quality supply and to the efficiency of electricity use that they will encourage. For example, canal water pricing reforms could facilitate broader acceptance of electricity pricing reforms besides mobilize necessary resources to fund operation and maintenance costs and foster a more efficient use of water. Other complementary measures, such as improving price incentives for farmers through increased investments in rural infrastructure and delivery of agricultural support services and safety nets, would improve returns to agriculture production and help mitigate the impact of raising electricity tariff. Finally, initiatives in ground water management involving regional and local user groups could provide a mechanism for workable collective self-enforcement to regulate the use and extraction of ground water resources.

Table 4.5 –Summary Recommendations

Key Actions	State Government	Electric Power Utilities
Power Sector	**Short-term:** -Communication Campaign for reform, i.e. sell "contract with farmers" - Initiate utility restructuring to bring efficiency and commercial orientation **Short to medium-term**: - promote decentralized generation options	**Short-term:** -Adopt tariff based on regulator recommendations -Improve collection efficiency/reduce theft -Improve staff accountability - Initiate Metering of all consumers **Short to medium-term:** -Make physical investments/rehabilitation - Initiate Integrated Approaches to Efficiency—adoption of more efficient pumps - Promote pilot rural electric cooperatives

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References

Aggarwal R. , 1997 “Risk Sharing and Transaction Costs in Groundwater Contracts: Evidence from India,” Working paper, University of Maryland, College Park.

Bhatia, Ramesh, 1975 “Tubewell Irrigation: Analysis of some Technical Alternatives, Economic and Political Weekly, Dec., pp 111-119.

Boothra K C, Bajaj N K; 1994, "Energy Conservation in Agricultural Electric Pumping System," National Seminar on Conservation of energy in agricultural pumping system, December 1994; Organized by Central Institute for Rural Infrastructure

Braverman, A. and Hammer, J. Multimarket analysis of agricultural pricing policies in Senegal. Singh, I. et al., editors. *Agricultural household models: Extensions, Applications, and Policy*. Baltimore: Johns Hopkins University Press; 1986.

Cason, T. N. and Uhlander, R. T. Agricultural production's impact on water and energy demand: A choice modeling approach. *Resources and En*ergy. 1991; 13:307-321.

Chambers, R. G. and Just, R. E. Estimating multioutput technologies. *American Journal of Agricultural Economics*. 1989; November:980-995.

Deaton, A., 1995*, “Data and Econometric Tools for Development Analysis,” in: J. Behrman and T. N. Srinivasan, eds., Handbook of Development Economics, Volume IIIA (Elsevier Science Publishers, Amsterdam).*

Dhawan, B.D. Development of tubewell irrigation in India*. New Delhi: Agricole Publishing Academy, 1982.*

Dias-Bandaranaike, R. and Munasinghe, M. The demand for electricity services and the quality of supply. *The Energy Journal*. 1983; 4(2):49-71.

Gardner R.L. and R.A. Young, 1984 “ The Effects of Electricity rates and Rate Structures on Pump Irrigation: An Eastern Colorado Case Study,” Land Economics, Vol. 60, No.4

Gisser, M. Linear programming models for estimating the agricultural demand function for imported water in the Pecos River Basin. *Water Resources Research*. 1970; 6(4):1025-1032.

Green, G.; Sunding, D.; Zilberman, D., and Parker, D. Explaining irrigation technology choices: A microparameter approach. *American Journal of Agricultural Econom*ics. 1996; 78:1064-1072.

Griffin, Charles, John Briscoe, B. Singh, Ramesh Bhatia, Radhika Ramasubban: Contingent Valuation and Actual Behavior: Predicting Connections to New Water Systems in the State of Kerala, India The World Bank Economic Review, Vol.9, No.3, 1995.

Gun Jav van der, K.Palanisami, Marcus Moench and Tushaar Shah : Draft Report prepared for the Workshop on Groundwater Regulation and Management, 1996

Howitt, R. E.; Watson, W. D., and Adams, R. M. A reevaluation of price elasticities for irrigation water. *Water Resources Research*. 1980; 16(4):623-628.

Just, R.E., D.L. Hueth, and A. Schmitz. 1982. *Applied Welfare Economics and Public Policy* (New York: Prentice-Hall).

Kolavalli, S. L. and Atheeq, L. K. *Groundwater utilization in two villages in West Bengal*. Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad. 1990(Draft).

Jain P C. 1994 "Energy Conservation awareness through high efficiency of utilisation in pumpiing systems," National Seminar on conservation of energy in agricultural pumping systems December 1994, Organized by Central Institute for Rural Electrification

Maddala, G.S., 1983, *Limited Dependant and Qualitative Variables in Econometrics*, Economertic Society Monographs No. 3 (Cambridge University Press, Cambridge).

Meinzen-Dick R. and M. Sullins, 1994, Water Markets in Pakistan: Participation and Productivity *(International Food Policy Research Institute, Washington D.C.).*

Moore, M. R. and Dinar, A. Water and land as quantity-rationed inputs in California agriculture: Empirical tests and water policy implications. *Land Economics*. 1995; 71(4):445-461.

Mundlak, Yair : Agricultural Growth and World Development. In A.Maunder and A.Valdezeds. *Agriculture and Governments in an Interdependent W*orld. Dartmouth Publishing Company. 1990

Narayanamoorthy, A. : Impact of Electricity Tariff Policies on the Use of Electricity and Groundwater: Arguments and Facts, *Artha Vijnana*, Vol. XXXIX No.3.September,1997 pp.323-340.

National Bank for Agriculture and Rural Development (NABARD) 1991, Report of the working group on lift irrigation schemes, NABARD, Mumbai, 1991

Padmanabhan, S. and Govindarajalu, C. *Power supply to agriculture, sub-task: Cost minimization options (inception repor*t). Inception Report. 1999 Jan 27.

Patel S M and Pandey M K, 1993 "Report on Complete Rectification's of Agricultural Pumps in Gujarat State," Institute of Co-operative Management, Ahmedabad, 1993.

Quizon, J. and Binswanger, H. Modeling the impact of agricultural growth and government policy on income distribution in India. *World Bank Economic* Review. 1986; 1:101-148.

Sadoulet, E. and de Janvry, *A. Quantitative Development Policy A*nalysis. Baltimore: Johns Hopkins University Press; 1995.

Saleth, R.M. : Power Tariff Policy for Groundwater Regulation : Efficiency, Equity and Sustainability, Artha Vijnana, Vol. XXXIX No.3 September, 1997 pp.312-322

Saleth, R. M and M. Thangaraj: Distribution Pattern of Lift Irrigation in India , An Analysis by Hydro-geological Regions, Economic and Political Weekly, vol. 28, No, 39, 1993

Sanghvi, A. P. Economic costs of electricity supply interruptions. *Energy Economic*s. 1982; July:180-198.

---. Optimal electricity supply reliability using customer shortage costs. *Energy Economics*. 1983; April:129-136.

Shah T., 1993, *Groundwater Markets and Irrigation Development: Political Economy and Practical Policy (Oxford University Press, Bombay).*

Taylor, D. C. Designing electricity rate structures for irrigation. *Land Economics*. 1989; 65(4):394-409.

Tisdell, J. G. The price of irrigation water. *Economic Analysis & P*olicy. 1996; 26(1):95-104.

Woo, C-K. and Toyama, N. Service reliability and the optimal interruptible rate option in residential electricity pricing. *The Energy Journal*. 1986; 7(3):123-136.

Wood, G.D. and R. Palmer-Jones, 1990, The Water Sellers: A Cooperative Venture by the Rural Poor (Connecticut, Kumarian press).

World Bank – Meeting India's Energy needs (1978-1999): A Country Sector Review – Report No. 19972, December 23, 1999

World Bank - The Political Economy of Water Pricing Reforms, Edited by Ariel Dinar, Washington DC, 2000

World Bank – India Foodgrain Marketing Policies: Reforming to Meet Food Security Needs, Report No. 18329-IN, August 1999

World Bank – India Water Resources Management Sector Review, Report No. 18416-IN, September 1998