Improving the Lives of India's Farmers

How Power Sector Reforms Will Help

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This booklet presents the main findings of the recent World Bank study, *India Power Supply to Agriculture,* 2001 carried out in the states of Haryana and Andhra Pradesh by the Bank's Energy Sector Unit, South Asia Region, in collaboration with the state governments.

Cover photo credit: Hemant Mehta

1. Unreliable Electricity Supply and Low Crop Production: A Possible Way out of the Vicious Cycle

Indian farmers who rely on electricity-powered pumps to irrigate their crops are continually plagued by power interruptions and voltage fluctuations, resulting in damage to their pumps, many lost irrigation days, and ultimately, lower crop yields and lower incomes. The poor condition of the power system makes it nearly impossible for farmers of every size – large, medium, small, and marginal[1] – to make rational cropping and investment decisions, including those that take account of the efficient use of water, land, and other natural resources. The poor reliability of power supply encourages farmers to pump as much water as possible when electricity is available. This, combined with the low and flat electricity tariff,[2] which results in no additional cost to farmers for pumping water, provides an incentive to farmers to follow the inefficient irrigation practice of flooding fields. Subsidizing electricity also encourages the cultivation of more water-intensive crops, which in some areas has resulted in declining ground water levels. This decline increases the demand for power to draw water from deeper in the soil, which in turn jeopardizes future agricultural performance.

This situation is compounded by the fact that power sector subsidies to agriculture, designed to compensate for farmers' low incomes, may actually encourage farmers to choose electricity-powered irrigation, by markedly reducing operating costs relative to alternative technologies, such as diesel. As a result, farmers dependent on electricity-powered irrigation are trapped in a vicious cycle of poor service, higher production costs, and lower incomes. This leads to political pressure to maintain the low tariffs, which in turn prevents investments that could improve the quality of electricity service to rural areas (please see Figure 1).

The current debate on power sector reforms in India is based on two key and contradictory assumptions that lead to two different results.

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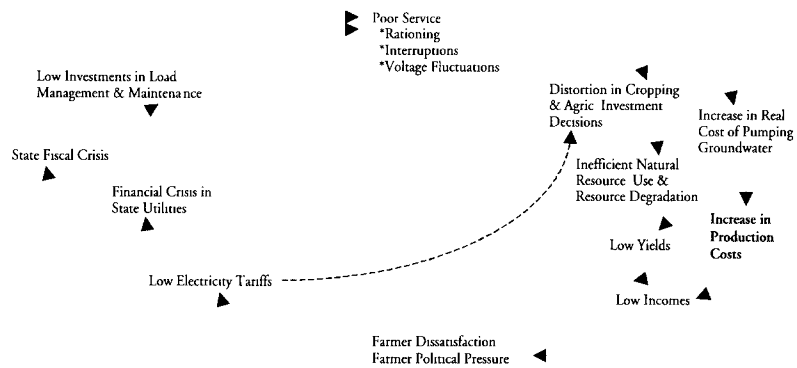
1 Large farmers are defined as those possessing more than 5 ha of land; medium as those with more than 2 and up to 5 ha; small as those with between 1 and 2 ha; and marginal as those with up to 1 ha.

2 Tariffs for irrigation pumps are based on the rated horsepower capacity of the electric motor.

Figure 1. Power Supply to Agriculture: The Vicious Cycle



Source: India Power Supply to Agriculture, Summary Report, 2001.

The first key assumption is that electricity tariffs must be kept low because higher tariffs would be a hardship to farmers. This assumption is based on the idea that nothing will change in terms of governance, management of the utilities, quality or reliability of supply, or any other factors that contribute to farmers' low incomes; and it leads to perpetuation of the vicious cycle.

By contrast, the second assumption – the one underlying the argument for tariff increases – is that higher tariffs will go toward financing needed maintenance, upgrading, and extension of the electricity network. These measures would lead to more reliable electricity supply for irrigation pumps and thus to higher productivity and higher incomes, thus offsetting the cost of the tariff increase. In other words, higher electricity tariffs would help farmers by creating a pathway out of the poor service/low productivity/low income trap. This assumption is predicated on the states undertaking systematic governance and regulatory reforms to ensure loss reduction, theft control, metering and collection, independent tariff setting, competition, and eventual privatization – all of which are necessary for a well-functioning power system.

This booklet demonstrates why the vicious cycle of low tariffs and low productivity can and must be broken, based on case studies in the Indian states of Haryana and Andhra Pradesh.

2. How Electricity Subsidies Hurt Agricultural Production

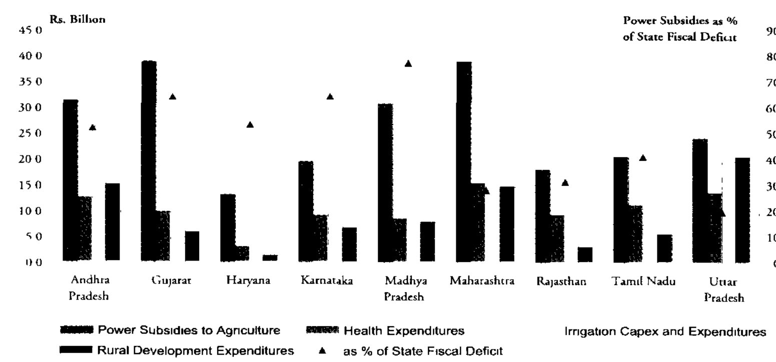
Electricity Subsidies are Large and Crowd out Other Expenditures in Rural Development

Electricity tariffs for agriculture amount to less than 10 percent of the cost of supply, with power subsidies for this sector totaling an estimated Rs. 270 billion (US$6.0 billion) per year. This equals about two and a half times the annual revenue expenditure for canal irrigation, two times the expenditure for rural development, two times the expenditure for health, and about 25 percent of India's fiscal deficit (please see Figure 2). If power subsidies to agriculture were reduced by only one third, the savings for a single year would be sufficient to fill every teacher vacancy in the country and provide every school with running water and toilet facilities.

Subsidized Electricity Supply is Unreliable and of Poor Quality, Resulting in Low Crop Yields

Although farmers pay a small fraction of the cost of electricity supply, they endure the frustration and economic costs of the supply being both unreliable (not available at predictable times) and of poor quality (with fluctuating voltage). Both problems mean that water often cannot be pumped during critical periods in the plant growth cycle, which negatively affects crop yields and farmers' incomes.

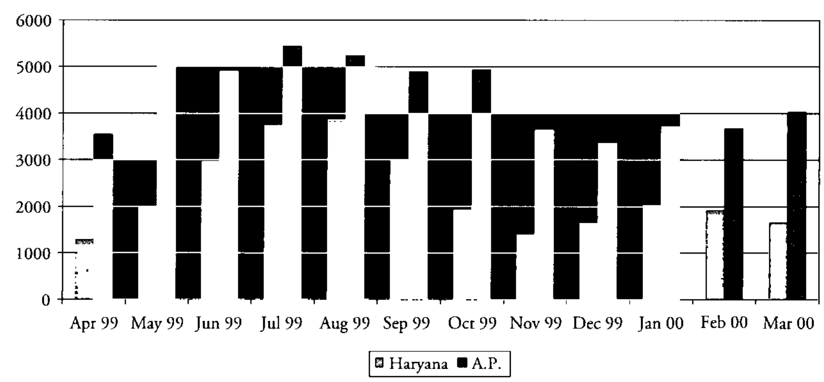
Figure 2. Power Sector Subsidies to Agriculture, Compared to Public Expenditures in other Sectors and as a Percentage of State Fiscal Deficit, FY 2000



Sources: *Reserve Bank of India. A Study of Budgets of 2001-2002,* December 2001;
Planning Commission, Annual Report on the Working of State Electricity Boards and Electricity Departments, June 2001.

✦ Under the current subsidized system, electricity is available to the agriculture sector mostly during off-peak hours – sometimes for as little as 3½ hours per day, due to power supply regulations and to the utilities' generally poor management of the network. At other times, there are unscheduled power cuts due to transformer failures, caused by overloading, unbalanced loading, or poor maintenance and protection of the equipment. In Haryana, transformers have a failure rate of 26 percent, and many of the failures – between 3,600 and 3,800 a month – occur during the kharif season (July and August), when irrigation requirements are highest. With paddy – rice grown as the main crop, all pumpsets work virtually simultaneously whenever power comes on stream, putting a tremendous load on transformers. At the same time, overall demand on the transformers increases significantly due to industrial and commercial demand for air conditioning. Repairs to transformers take an average of 10 days, during which farmers have no power for their irrigation pumps and must rely on back-up diesel pumps, if they can afford them. In Andhra Pradesh, the incidence of transformer burnout is 29 percent – between 5,200 and 5,400 failures a month (please see Figure 3) – and farmers have no electricity for an average of 4 days while the transformers are being repaired. High rates of transformer failure continue during the summer and the kharif seasons. Extensive rural networks with long low-voltage lines with very thin conductors are among the other main reasons for transformer failure in Andhra Pradesh.

Figure 3. Monthly Transformer Failures in Haryana and Andhra Pradesh



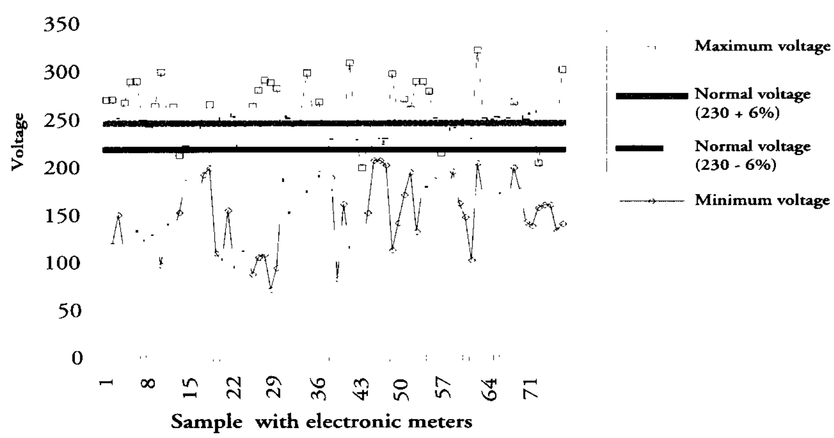
Sources: Data from HVPNL (Haryana electric utility) and APTRANSCO (Andhra Pradesh electric utility), FY2000.

In addition to affecting farmers, the need for continual repair of transformers also puts a financial strain on the utilities.

- **Poor quality of supply**. Under the current subsidized system, power supply is characterized by voltage fluctuations and imbalances. In some parts of Haryana, farmers receive power supply at normal voltages +/- 6 percent (as per Indian Electricity Supply Rules) only 20 to 40 percent of the time (please see Figure 4). This low quality supply significantly affects the operating efficiency of electric pumps, and is a major factor contributing to pump burnouts. Imbalances in three-phase supply[3] also strain pump motors and accelerate burnouts.

In addition to the loss of crops, farmers must bear other costs to compensate for the unreliability and poor quality of supply. The repair of a burned-out motor costs about half of the yearly electricity tariff that farmers pay for each pump. While some farmers purchase back-up diesel pumps, or over-invest in larger pumps in the hope of pumping more water when electricity is available, small and marginal farmers can least afford these coping strategies – and about 40 percent of farmers who own electric pumps in Haryana, and 48 percent in Andhra Pradesh, are small and marginal.

Figure 4. Range of Supply Voltage Received at Pumpsets



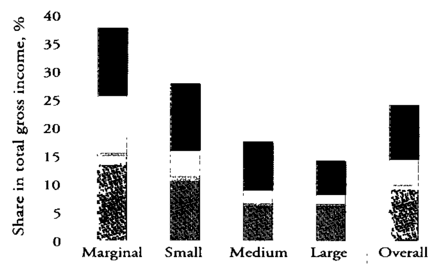
Source: India Power Supply to Agriculture, Volume 2, Haryana Case Study, 2001.

[3] Traditionally in India, irrigation pumps have been designed for a three-phase power supply system. One or two-phase power is supplied to residential, and other users with low load.

Subsidies are Mistargeted to Larger and Richer Farmers

Large farmers are more vocal in favor of retaining the subsidized flat rate per pump because it represents a manageable proportion of their gross income, and makes it possible for them to irrigate a large area at lower per unit cost (please see Figure 5).

Figure 5. Power Subsidy Benefits to Larger Farmers
(lower share of tariffs in gross farm income)

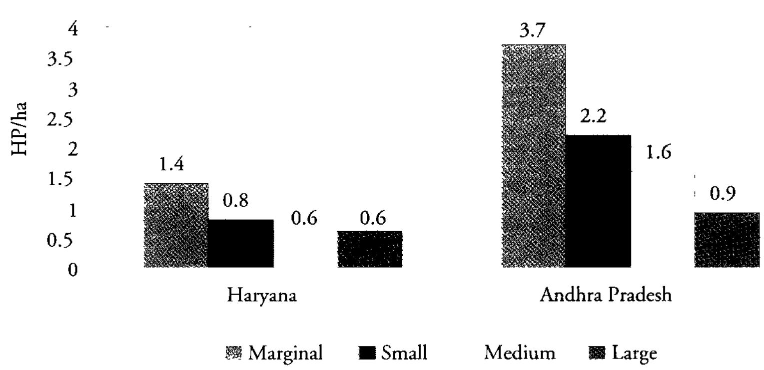


	Marginal	Small	Medium	Large	Overall
Fixed cost of pump and well/yr	12.1	11.9	8.6	6	9.7
Purchase of water	0	0.01	0	0	0
Motor burnout	10.15	4.56	2.39	1.64	4.52
Pump maintenance	2.22	0.93	0.43	0.37	0.94
Tariff	13.27	10.42	6.09	6.08	8.84

Source: India, Power Supply to Agriculture, Volume 2, Case Study Haryana, 2001.

But small farmers who can afford electricity must pay the same tariff per pump as large farmers to irrigate a much smaller area. For those small farmers, the irrigation cost per hectare is significantly higher than it is for larger farmers (please see Figure 6). As a result, electricity tariffs represent 13 percent of the gross farm income of marginal farmers, in contrast to 6 percent for large farmers.

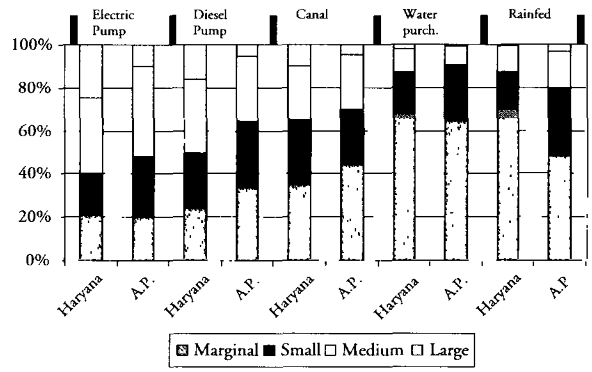
Figure 6. Flat Electricity Tariffs Benefits to Larger Farmers
(lower horsepower level, by gross cultivated area)



Source: India, Power Supply to Agriculture, Volume 2, Case Study Haryana, 2001.

Moreover, electricity subsidies do not even reach the majority of small and marginal farmers, who do not have access to electricity and rely mostly on rainfall to irrigate their fields (please see Figure 7). In Haryana, for example, electric pump owners have net incomes one-third above the average for the state's farmers, and four times that of farmers who rely exclusively on rainfed cultivation.

Figure 7. Distribution of Farmers by Type of Technology, Haryana and Andhra Pradesh



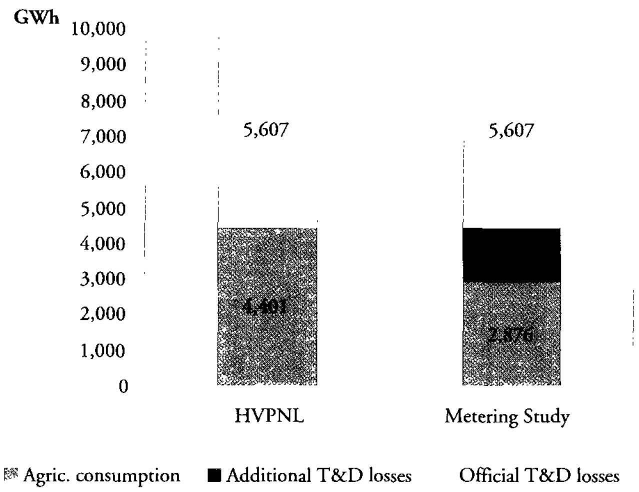
Sources: India Power Supply to Agriculture, Volume 2, Case Study Haryana, 2001 and *Volume 3, Case Study Andhra Pradesh,* 2001.

Subsidies in the Form of a Flat Rate Camouflage Theft, and Hurt the Utilities Capacity to Provide Reliable Service

Since electricity subsidies take the form of a flat rate per horsepower per pump, actual usage is not metered or recorded. To estimate actual usage in Haryana, meters were installed on a sample of 584 pumpsets and their readings recorded biweekly for a year. The results showed that farmers' actual consumption is 27 percent lower than estimated by the utilities (please see Figure 8); thus transmission and distribution losses are correspondingly higher than the utilities claim. These incremental losses cost the utilities about Rs. 7 billion (US$160 million) per year. A large part of these losses, which affect the utilities' ability to provide reliable service to farmers, are due to pilferage by commercial, residential and low-voltage industrial customers.

From the utilities' point of view, providing power to agriculture costs more than supplying industry and urban residents, because of the much higher fixed infrastructure costs and line losses associated with serving connections spread

Figure 8. Losses Camouflaged by Official Consumption Figures



Note: T&D=transmission and distribution. The study estimates that agricultural consumption is 27 percent lower than official estimates; total losses are therefore 47 rather than 33 percent.

Source: India, Power Supply to Agriculture, Volume 2, Case Study Haryana, 2001.

across the countryside. Moreover, the political pressures on utilities to maintain electricity subsidies to agriculture have left them without adequate revenues to finance the repair, maintenance, and extension of transformers and power lines – all of which are necessary to provide farmers with more reliable and better quality electricity supply.

As Service Quality Deteriorates, Farmers are Increasingly Unwilling to Pay

Due to the inadequate and deteriorating quality of electricity supply, farmers are increasingly unwilling to pay even highly subsidized charges. As farmers postpone paying electricity bills, utilities are even less able to make the investments needed to improve service – thus further perpetuating the vicious cycle.

3. Breaking the Vicious Cycle through Tariff Reform

India has generally accepted the idea that tariff reform is needed if electric utilities are to perform at high levels of efficiency, satisfy the expectations of farmers, and reward their higher payments with quality power supply. The expectation of these improvements, of course, is based on the assumption that: (1) farmers will understand and accept the urgent need for tariff increases; (2) the new revenue flows will be invested in maintaining and upgrading the system; and (3) tariff reform will take place in the context of broad governance and regulatory reforms and corporate restructuring, to ensure that utilities operate efficiently and equitably.[4]

Tariff reform needs to be immediately addressed, even though the broader reforms will require a longer-term effort. To facilitate the acceptance of tariff increases, these increases must be linked to efficiency improvements and implemented on a pilot basis in specific areas of each participating state. The pilots can later be scaled up in a phased manner to cover the entire state.

Small and marginal farmers in Haryana (about 40 percent of the electric pump-owning population) have shown a high willingness to pay for improved quality and reliability of power supply, since they are most severely affected by power supply problems. Medium and large farmers (about 60 percent) have shown relatively less willing to pay in the short run, due to their expensive back-up arrangements (diesel) and, consequently, their lower vulnerability to power supply fluctuations. This has major implications for both the efficiency of resource use and the equity of tariffs. Since improved efficiency in the delivery of water and power is, in the short run, of less concern for the majority of farmers, the smaller and poorer farmers end up bearing the cost of wasted resources and unreliable supply. To improve both equity and the efficient use of water resources, it is therefore imperative to shift to energy metering and per-unit tariffs.

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[4] Six states in India – Haryana, Andhra Pradesh, Karnataka, Orissa, Rajasthan, and Uttar Pradesh – have requested World Bank assistance in designing power sector reforms that include governance, regulatory and corporate restructuring, and privatization. All six envision increased tariffs as part of these reforms. In the longer term, the reform agendas of all six states ultimately envision privatized, commercial utility operations; regulation of the utilities by independent agencies that operate without political interference; and more competitive power markets.

Simulations Show that Farmers of all Sizes Would Benefit Significantly from a Program of Tariff Reform and System Upgrading

To provide farmers with a better understanding of the potential impact of tariff reform, the World Bank has developed three policy reform scenarios (please see Table 1). Scenario I is business as usual, where tariffs would inevitably increase just to keep the utilities functioning, but quality would deteriorate due to the absence of infrastructure investments. Scenario II is gradual reform, with a steeper tariff increase and some improvement in quality indicators. And Scenario III is accelerated reform, with the same tariff increase as in Scenario II, but more aggressive quality improvements. The simulations show that combining agriculture tariff increases with a phased program of improvements – not only in physical infrastructure, but also the utilities' capacity to manage loads, decrease service time, increase transparency and accountability, reduce theft, and improve collections – would significantly benefit farmers, especially small and marginal farmers.

In particular, at a gradual reform pace (Scenario II), with a phased tariff increase of 470 percent over six years (so that tariffs would cover about 60 percent of the cost of supply), and improvements in the availability and quality of power supply and the speed of transformer repair, farm incomes of small and marginal farmers would increase by nearly 50 percent. Farm incomes of medium and large farmers would also increase by 10 to 20 percent. Under an accelerated reform (Scenario III), with the same phased 470 percent increase in tariffs but a more rapid improvement in power supply due to more aggressive physical investments and institutional reforms, farm incomes of small and marginal farmers would increase by 100 to 120 percent, and incomes of medium and large farmers by 40 to 50 percent. However, if agricultural tariffs were increased by only 200 percent (to cover 30 percent of the cost of supply) and no reform package were put in place, so that power supply conditions would continue to deteriorate (Scenario I), the income of medium and large farmers would decline by about 50 percent. Before the end of year six under this scenario, small and marginal farmers would find the use of electric pumps no longer sustainable (see Table 1).

Benefits also Depend on Farmers Using Energy More Efficiently

Both reform scenarios would involve a transition period, during which tariffs would go up and the quality of supply would at first be uneven but improve over time. Small and marginal farmers, who are most affected by variations in quality, could reduce their costs during this period by investing in smaller pumpsets with more efficient motors, which pump the same amount of water using less electricity. Farmers' willingness to invest in new pumpsets would, of course, depend on efforts to improve the quality of supply as quickly as possible, so as to

Table 1. Policy Reform Simulations: Impact of Power Reform on Farmer Incomes in the Medium Term (6 years)

	Scenario I: No Reforms		Scenario II: Gradual Pace		Scenario III: Accelerated Reforms	
	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
Base year tariff (Rs.)	2,410	5,650	2,410	5,650	2,410	5,650
Post-reform tariff (Rs.) (% change)	7,560	17,700	13,830	32,380	13,830	32,380
	(200%)		(470%)		(470%)	
Cost recovery at the end of year 6 (tariff as a percentage of cost of supply)	30%		60%		60%	
Post-reform availability (% change)	8.1 hours/day (0%)		9 hours/day (11%)		10 hours/day (23%)	
Post-reform reliability – duration of power cuts during availability (% change)	5.2 hours/day (99%)		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%)		3.3 days (-66%)	
Post-reform frequency of motor burnouts/ year (% change)	2 (99%)		0.6 (-42%)		0.33 (-67%)	
Change in real net farm income over base year (%)	Use of electric pumps no longer sustainable	-46 to -55%	47 to 48%	12 to 18%	100 to 121%	37 to 48%
Tariff coverage of cost of supply by end of year 6	30%		60%		60%	

Note: Calculations are based on the assumption that output and other input prices will remain constant in real terms.

Source: India Power Supply to Agriculture, Volume 2, Case Study, Haryana, 2001.

minimize the risk of pump burnouts (please see Table 2 and Box 1). Given this risk, an incentive package may be needed to encourage farmers to invest in new pumpsets while offering some kind of insurance against the cost of burnouts, until the quality of supply is more consistent.

Table 2. Energy Savings from Replacing Pumpsets

Step	Measure	Energy Conservation Potential (percent)
1	Replacement of Galvanized Iron (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

Over the proposed six-year reform period, during which the quality of power supply is expected to improve, the cost of a new pumpset – as well as the cost of the more realistic per-unit tariff – would be completely offset by the farmer's higher productivity and farm income. States that encourage energy conservation as part of their reform package could offer incentives to rural cooperatives or village electricity committees to help farmers purchase more efficient pumpsets.

The importance of more efficient pumpsets cannot be overstated. In Haryana, a detailed survey of pumpset efficiency in four feeders revealed that pumpsets operate at an efficiency level of 21 to 24 percent, well below their technical and economic potential. About a quarter of the pumps surveyed had an efficiency of less than 20 percent, about half were in the 10 to 20 percent range, while only a remaining quarter had an efficiency higher than 30 percent, and only 2 percent were above 40 percent. Frequent motor burnouts and rewinding were found to be major factors contributing to reduced operating efficiency. The survey also indicated that a dual approach of replacing or rectifying inefficient pumpsets, and rehabilitating of the distribution system, would produce maximum energy savings (Box 1).

This dual approach was piloted in Andhra Pradesh in the early 1980s. That program had mixed results, due to several factors, including: (1) the resistance of farmers (and unauthorized users) to a new single-phase distribution system and the mandatory conversion to more efficient pumps; (2) the inability of utilities to monitor consumption; and (3) the absence of a mitigation plan for local

Box 1. Pumpset Rectification and Rehabilitation of the Distribution System in Haryana

Pumpset rectification has traditionally involved replacing foot valve and suction and delivery piping to reduce frictional losses and increase water delivery potential. However, the study found that the benefits are only realized if the pumpset is replaced by a lower-rated but more efficient pumpset. A new pumpset makes it possible to deliver same amount of water for significantly lower energy consumption.

Field studies in Haryana on four 11kV feeders (Bastara, Alampur, Handikera, Gujjarwas) indicate that, if pumpset replacement is implemented in conjunction with rehabilitation of the distribution system, overall system efficiency could reach 50 percent. In addition, rehabilitation of the agricultural feeders would extend the operational life of the pumpsets, since improving the quality of power supplied would reduce pumpset burnouts.

mechanics whose livelihoods were threatened by the contractor-implemented pumpset program (please see Box 2).

Issues for Policymakers

Many farmers understand that improved electricity service depends on higher tariffs and metering, although fewer understand the need to invest in more efficient pumpsets. To ensure continued and increasing support as power sector reforms are put into action, policymakers must clearly define, communicate, and gain consensus for a strategy that balances higher costs with improved performance, over a timeframe that small and marginal farmers, in particular, find acceptable. The key will be to offer incentives and support to make the transition as painless as possible.

Two basic measures are essential:

- Communication and consumer awareness. A campaign to foster increased awareness and understanding of the current unsustainable situation in the power sector is vital to achieving broad-based consensus and support for reform. Farmers should be consulted about, and participate in, decisions about how to sequence quality improvements and tariff increases. In addition to publicizing 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 impact on the quality of power supply.

Box 2. Agricultural Demand-Side Management in Andhra Pradesh

In the early 1990s, Andhra Pradesh recognized the potential benefits of introducing end-use efficiency in agriculture, and the prerequisite need for a steady and high-quality power supply. The state pioneered the concept of integrated energy efficiency in India through a two-fold approach: the introduction of a single-phase high voltage distribution system (HVDS) to improve the quality of supply; and the replacement of inefficient pumps with higher-efficiency and lower-capacity pumps to reduce energy consumption per unit of water delivery. Small-capacity single-phase transformers (10 or 15 KVA) were to be installed to supply a small group of 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 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 of UK DfID in Nalgonda district, involving 3,200 pumpsets connected to one 33/11 kV substation. Losses were brought down to about 2.5 per cent in the low-voltage section. However, only about 850 consumers participated in the demonstration project.

Learning from this experience, Andhra Pradesh is now adopting a modified approach in the AP Integrated Agricultural Energy Efficiency pilot project, funded by a US$4.6 million grant from the Government of Norway. This pilot covers approximately 5,800 pumpsets connected to two 33/11 kV substations in Chittoor and Karim Nagar districts. Under this pilot, HVDS will be developed in a three-phase configuration, to eliminate one of the farmers' main concerns.

An outreach program explaining the benefits of the new distribution system and a voluntary scheme to purchase efficient pumpsets will be offered to farmers, in close coordination with local groups and banks involved in rural development. It is expected that end-use efficiency will increase an average of 25 to 50 percent. The pilot is expected to be completed by December 2002.

- Metering. This measure is essential for several reasons: reducing theft, facilitating end-use efficiency improvements, and implementing appropriate pricing policies (e.g., eliminating the regressive impact of flat-rate tariffs and increasing transparency regarding the consumption levels of various types of consumers). Metering of all consumers will help to determine farmers' consumption, and therefore help reduce losses and pilferage by other consumers. Metering will also allow better targeting of subsidies to those farmers who most need them.

As power sector reforms proceed and electricity for irrigation pumpsets becomes more available and reliable, farmers in India can better and more sustainably capitalize on the productive potential of their land. More reliable water supply will help improve agricultural productivity and incomes, and open opportunities for diversification to higher-value crops. In combination with more equitable tariffs, more reliable water supply will also encourage the use of improved water-conserving technologies, such as drip or sprinkler irrigation, which help conserve precious water resources. Improving rural power supply will also help improve the investment climate for rural industrial activities and services. This could, in turn, generate much-needed employment and income opportunities in rural areas, where a large share of the poor reside. Taken together, these reforms will help sustain the livelihoods and improve the quality of life of farmers and rural communities over the long term.

The World Bank will continue to work with India on the design and implementation of these and other reforms in the power sector, including governance and regulatory reforms to help stimulate the economic and social development of the country.

This booklet is based on the four-volume study, *India Power Supply to Agriculture* (World Bank 2001), consisting of the *Summary Report* (Volume 1); the *Haryana case study* (Volume 2); the *Andhra Pradesh case study* (Volume 3); and the *Methodology Framework Report* (Volume 4). The complete study is available at www-wds.worldbank.org, key word India.

The report contains the findings of the following technical background studies:

- A metering study to monitor power consumption by a representative sample of 584 pumpsets in Haryana. Electronic meters to measure the quality of power were installed on 76 of these pumpsets.

- Farmers' household surveys, including: (1) attitude surveys of 687 farmers in Haryana and 525 farmers in Andhra Pradesh to assess their views on power supply conditions; and (2) recall surveys of electric and diesel pump owners, canal users, water purchasers, and rainfed farmers. The surveys covered representative samples of 1,659 farmers in Haryana and 2,120 farmers in Andhra Pradesh. Data were collected over the full crop year: the rabi season (December 1999-April 2000), the summer season (June-July 2000); and the kharif season (August-November 2000) in Haryana; and for the summer season (April-June 1999), kharif season (June-November 1999), and rabi season (December 1999-April 2000) in Andhra Pradesh.

- Feeder studies, to monitor the availability, reliability, and quality of power supply in four 11kV distribution feeders (Kalyana, Nalikalan, Janesroan, and Khijuri) in Haryana, using specially programmed meters that recorded voltage and current at five-minute intervals. Data were collected during the kharif season 1999, and the rabi season 2000.

- An econometric analysis, using the primary data collected from the metering and feeder studies and household surveys, to gauge the impact of power supply conditions on farmers' irrigation technology choices, farm incomes, and electricity demand. The parameter estimates obtained from the econometric model were used to conduct various policy simulation exercises.

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