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SOUTH ASIA ENERGY STUDIES

Lighting Rural India:
Load Segregation Experience in Selected States

February 2014

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The International Bank for Reconstruction and Development/
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Lighting Rural India:
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Contents

Boxes

Figures

Tables

Foreword

Socioeconomic development of the rural populace is critical to India achieving its stated objective of inclusive growth. It is widely accepted that access to a reliable and sufficient power supply is a key enabler of rural economic growth. Traditionally, India's rural power supply has been restricted by having feeders to villages serve both agriculture and household loads. Because agriculture power supply is rationed by the distribution utilities, residential consumers often suffer from inadequate service.

In 2003, some states in India began to separate their agriculture and non-agriculture electricity loads in rural areas to provide household consumers increased hours of power supply while restricting supply to agriculture loads. This practice has led to significant improvement in the overall socioeconomic status of the rural population, resulting in various states requesting financial assistance from the Ministry of Power to undertake similar programs. In response, the Ministry of Power is planning to formulate a large central scheme that will provide states funding to undertake feeder segregation. At the Ministry's request, the World Bank carried out this study to assess the experience of states that have already undertaken rural load segregation. The study's significant findings and recommendations, documented in this report, can be used to improve the overall positive impacts of the program.

The study findings reveal that segregated systems can be used to manage peak demand, identify and reduce losses previously hidden in agricultural consumption, improve power supply to rural domestic consumers, and bolster socioeconomic development. Enabling the segregated system with information technology (IT) can further improve monitoring and control and bring about transparency and efficiency: Agricultural consumption on which the subsidy is based can be exactly determined, even without consumer metering, and data collected from the system can be used for strategic decision making and operational improvement.

That said, all of the many benefits of feeder segregation may not necessarily be realized in every case. For this reason, the study recommends that each state design a rural power supply system customized to suit its local conditions and desired outcomes. The study further recommends that a central knowledge hub be set up by the Government of India to assist states in undertaking such improvement programs. I am pleased to note that the World Bank will provide the government support in setting up this knowledge hub, along with continued strengthening of the design and implementation of rural power supply programs, ultimately benefiting the socioeconomic progress of 800 million rural people in India.

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Acknowledgments

This report summarizes the findings of a World Bank study on India's recent experiences in rural feeder load segregation, undertaken at the request of India's Ministry of Power. The study was led by Ashish Khanna and Mohua Mukherjee, with a core team including Sudeshna Ghosh Banerjee, Kavita Saraswat, and Mani Khurana of the Energy Sector Unit, South Asia Sustainable Development.

The study benefited from a background study prepared by staff of Pricewaterhouse Coopers Private Ltd, who interacted with the distribution utilities and shared data and first-hand experiences with other key stakeholders, as well as a consumer survey led by MRS Private Ltd. The team wishes to thank officials of the distribution utilities and the respective Principal Secretaries of Energy in the states of Andhra Pradesh, Gujarat, Haryana, and Rajasthan for their cooperation and generous support. It also extends special thanks to counterparts in the Ministries of Power and Finance, who provided constructive guidance throughout the study. The report was edited by Norma Adams and typeset by Laura Johnson.

The team wishes to thank Jyoti Shukla, Senior Manager, and peer reviewers Tushar Shah of the International Water Management Institute and Mohinder Gulati and Pedro Antmann of the World Bank for their useful insights during preparation of the study. Finally, the team gratefully acknowledges the generous funding support provided by the World Bank's Energy Sector Management Assistance Program (ESMAP), Asia Sustainable and Alternative Energy Program (ASTAE), and Office of the Chief Economist, South Asia Region.

Acronyms and Abbreviations

ABC	Aerial Bunched Cables
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
AT&C	Aggregate Technical & Commercial
CAPEX	Capital Expenditure
DPR	Detailed Project Report
DT	Distribution Transformer
EIRR	Economic Internal Rate of Return
FRP	Feeder Renovation Program
GUVNL	Gujarat Urja Vikas Nigam Ltd
HT	High Tension
HVDS	High Voltage Distribution System
IRR	Internal Rate of Return
IT	Information Technology
JGY	Jyoti Gram Yojna
JVVNL	Jaipur Vidyut Vitran Nigam Ltd
LT	Low Tension
M&E	Monitoring and Evaluation
MIS	Management Information System
MKVVCL	Madhya Kshetra Vidyut Vitran Company Ltd
PGVCL	Pashchim Gujarat Vij Company Ltd
PMU	Project Management Unit
PPP	Public Private Partnership
PwC	Pricewaterhouse Coopers
REC	Rural Electrification Corporation Ltd
RMR	Remote Meter Reading
RVPNL	Rajasthan Rajya Vidjut Prasaran Nigam Ltd
SDT	Special Design Transformer
UGVCL	Uttar Gujarat Vij Company Ltd
VCB	Vacuum Circuit Breaker
XPLE	Cross-Linked Polyethylene

Units of Measure

GWh	gigawatt hour
ha	hectare
km^2	square kilometer
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt hour
mm	millimeter
MW	megawatt

Currency Equivalents

Currency unit = Indian Rupee (Rs.)

Rs. 53 = US$1 (January 2012)

Executive Summary

Subsidizing electricity for irrigated agriculture in India dates back to the advent of the Green Revolution in the late 1960s. Decades later, those subsidies remain in place, and electricity tariffs for farmers amount to less than 10 percent of the cost of power supply. Typically, farmers are charged a flat tariff rate based on the horsepower per pump rather than the level of power actually used, which is not metered or otherwise recorded. Because mixed feeders in villages supply both agriculture and non-agriculture loads, the amount of power consumed cannot be disaggregated by farm or non-farm use or by the amount of power lost to technical inefficiencies or pilferage. High system transmission and distribution losses, estimated at 35 percent, basically camouflage theft. The absence of metering, along with the extremely low cost of supply, means that rural agriculture consumers lack incentives to conserve and control their power use.

Today, the agriculture sector accounts for 20–45 percent of total power sale in most Indian states; in some states, the agriculture power subsidy equals twice the expenditure on health or rural development. Empirical evidence suggests that large farmers have benefited disproportionately from the subsidy policy. Most small and marginal farmers lack access to electricity, instead depending on rainfed agriculture. Within an environment of chronic shortages and wasteful consumption that threatens groundwater depletion, state utilities have sought to limit the subsidy burden by restricting daily agriculture power supply to 6–8 hours, often at night. But this practice compromises the quality and quantity of supply to non-farm consumers connected to the same feeder, constraining their productive economic activities.

One pragmatic solution tried by some states is rural feeder load segregation, which physically or virtually separates paid and nominally-paid rural feeder loads. By separating agriculture and non-agriculture connections, utilities can attempt to measure and limit the amount of power supplied free to farmers for irrigation, while ensuring that non-agriculture consumers receive better-quality supply for longer periods throughout the day. To date, eight states have initiated such schemes: Andhra Pradesh, Gujarat, Haryana, Punjab, Karnataka, Maharashtra, Madhya Pradesh, and Rajasthan.

Against this backdrop, the World Bank, at the request of India's Ministry of Power, undertook a study of India's experience in rural load segregation. The study's overall goal was to draw lessons that can be applied to implementing such schemes more broadly across the country. The study had four main objectives. The first was to compare load segregation approaches tried in various states to draw lessons that can be applied to future programs. The second was to evaluate the financial viability of the schemes based on financial and operational parameters. The third was to gain a better understanding of the socioeconomic benefits of the schemes by conducting a primary survey of rural end-user consumers. The fourth was to develop a guidance note that policy makers can use to formulate a national action plan on rural feeder load segregation. The study was divided into four parts aligned with these objectives.

The study used an institutional framework to evaluate key parameters across the project cycle, while financial and economic frameworks were used to analyze costs and benefits. Four states—Andhra Pradesh, Gujarat, Rajasthan, and Haryana—were selected for the study. Selection criteria included the amount of time elapsed since completion of the feeder segregation scheme, type of technical intervention used, and coverage composition. In Andhra Pradesh, where data collection is ongoing, key lessons will not be finalized until analysis for all selected states has been completed. Gujarat completed its feeder load scheme in 2006, while Rajasthan's program is ongoing. In Haryana, feeder segregation was completed in mid-2010; only the first part of the study was applied since commenting on the scheme's impact was considered premature.

Findings show that the states analyzed share a common goal of ensuring adequate supply hours to farmers and non-agriculture rural consumers to support socioeconomic development. Other common drivers of implementing load segregation are ensuring rural consumers good-quality, reliable power supply, enhancing energy accounting and auditing leading to a restatement of agricultural consumption and thus loss levels, and enhancing load management through supply rotation for agriculture consumers.

The technical approach selected for feeder load segregation has been unique to each state's political thinking, regulatory policies, and state of the power sector. Both Andhra Pradesh and Gujarat initially undertook virtual segregation and later switched to physical segregation to eliminate theft and frequent power outages. To address groundwater issues, Gujarat incorporated feeder segregation into its integrated rural development program. Rajasthan chose a virtual scheme that became part of its feeder renovation program (FRP). Haryana adopted a physical segregation approach to tackle the problem of high distribution losses in the power sector. **Before-and-after analyses to assess the direct benefits from load segregation were not possible since no baseline data collection and analysis had been undertaken.**

Project costs varied by state, depending on the technical approach adopted and whether the system architecture was stand-alone or integrated. The capital investment per feeder varied from US$64,150 (Rs. 3.4 million) in Andhra Pradesh to $128,302 (Rs. 6.8 million) in Gujarat, while capital investment per kilometer ranged from $377,358 (Rs. .20 million) in Andhra Pradesh to $624,528 (Rs. .33 million) in Haryana. Because project scopes differed by state, direct cost comparisons were not feasible.

No specific institutional frameworks had been put in place to execute the feeder load segregation schemes. With the exception of Rajasthan, where the circle head was designated as project manager for the FRP, the segregation schemes had been managed as part of routine business operations, with no dedicated project management units. In Andhra Pradesh, Rajasthan, and Haryana, the states' respective distribution utilities were considered the project owner—defined as the entity that initiates the scheme and owns it through the implementation phase—while the state government was the project owner in the case of Gujarat.

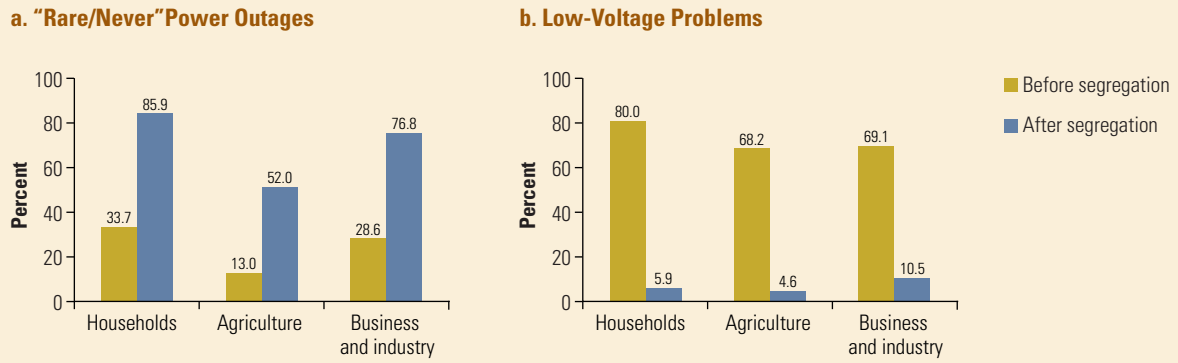
Andhra Pradesh, Gujarat, and Rajasthan decided to undertake pilots before initiating statewide rollout of load segregation. Although Haryana did not undertake a pilot, official field visits were made to Gujarat and Andhra Pradesh to gain insights from these states' experiences. The extent to which lessons from the pilots were integrated into final project designs is unclear since there is no formal documentation on pilot results. **None of the schemes included components of remote meter reading or advanced metering infrastructure,** which are used to capture online metering data and prepare a user-friendly management information system (MIS) to undertake measurement and control of agricultural consumption.

For all states, the study found that monitoring and evaluation (M&E) of project execution and outcomes had been negligible. For example, summary reports on agricultural consumption based on segregated load data had not been prepared for management decision making in Gujarat and Rajasthan even four and five years, respectively, after project completion. As mentioned above, baseline data studies were not conducted prior to load segregation in any of the states, and development of an MIS tool to measure and monitor agricultural consumption in rural areas had not been envisaged as part of the schemes. However, Gujarat undertook a post-scheme evaluation through third parties, and Haryana recently designed an M&E framework to accurately estimate agricultural consumption post segregation and ensure transparency in determining subsidy levels.

Rural load segregation is expected to provide quantifiable financial returns through two main channels: (i) increased revenue accrued to the utility as a result of loss reduction and/or changes in the sales mix of the project area **and (ii) reduced cost** achieved through lower power-procurement cost at the margin. Analysis of the financial benefits of rural load segregation was based on a detailed data assessment of two rural subdivisions: Vinchiya (Gujarat) and Bassi (Rajasthan). Findings at the level of these subdivisions were then aggregated to all rural subdivisions at the level of the respective distribution utilities and finally the states.

Rural load segregation has been a critical factor in bringing transparency to agricultural consumption, resulting in accurate estimates of distribution losses. In Vinchiya, sales to the agriculture sector between 2006 and 2010 decreased by more than half of total energy input, while distribution losses increased by about as much. Revenue gain over the period can be attributed, in part, to growth in non-agricultural consumption. The utilities achieved transparency in agricultural consumption and estimating distribution losses. The physical separation of agriculture supply from continuously supplied household and commercial connections empowered the utility to plan load rotation on agriculture-dominant feeders and improve peak demand management. In Bassi, the ongoing FRP contributed significantly to reducing distribution losses, but there was no loss restatement as in Vinchiya. Utility sales to the agriculture sector post segregation grew by about 8 percent of total energy input, while distribution losses fell by 16 percent. Both metered and unmetered agriculture connections rose consistently. Despite loss reductions achieved through virtual segregation, higher

FIGURE ES.1 CHANGES IN QUALITY OF SUPPLY, VINCHIYA SUBDIVISION, GUJARAT



Source: MRS Private Ltd Survey 2011.

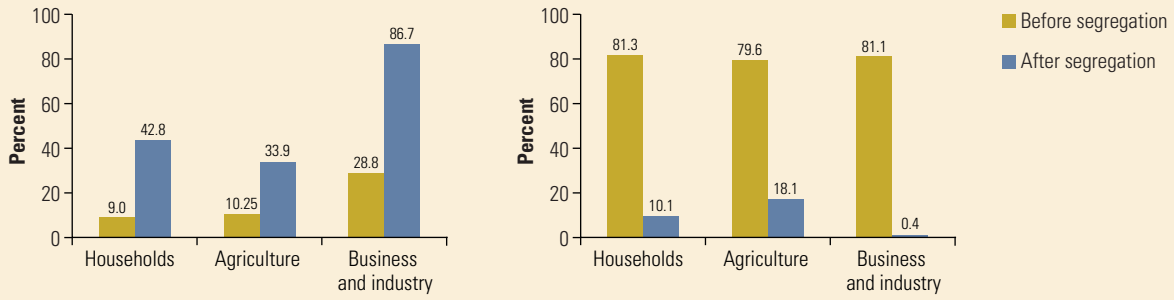
sales to agriculture, along with a dwindling subsidy disbursement, pressured the state's fiscal viability.

Rural feeder segregation is envisaged to improve welfare outcomes through two direct channels: (i) better quality and reliability of electricity supply and (ii) socioeconomic benefits. Better quality of supply comprises such issues as voltage, outage frequency, and data on system balancing and failure rate of distribution transformers, while socioeconomic benefits refer to non-agriculture consumers' increased hours of electricity supply. The study analyzed the welfare outcomes for these two variables in Vinchiya (Gujarat) and Bassi (Rajasthan).

Survey findings show a marked improvement in quality and reliability of supply resulting from feeder segregation. The percentage of households in Vinchiya (Gujarat) that reported power outages as "rare/never" increased by more than 150 percent (figure ES.1a), while those reporting low-voltage problems decreased by about 74 percent (figure ES.1b). Similarly, the failure rate of distribution transformers for the utility fell from 24.18 percent in FY2006–07 to 19.79 percent in FY2008–09. In Bassi (Rajasthan), the percentage of households that reported power outages as "rare/never" increased by nearly 34 percent (figure ES.2a), while those reporting low-voltage problems fell by more than 71 percent (figure ES.2b). Results of focus group discussions show that farmers were satisfied with scheduled power supply with minimum interruptions.

The financial and economic results of improved power supply in Gujarat and Rajasthan have been mixed, suggesting the need for integrated analysis. Gujarat has managed to control the subsidy and financial losses, while overall financial losses and subsidy in Rajasthan continue to increase. To derive the maximum benefit from investments,

FIGURE ES.2 CHANGES IN QUALITY OF SUPPLY, BASSI SUBDIVISION, RAJASTHAN



Source: MRS Private Ltd Survey 2011.

institutional and governance reforms need to accompany technological changes. Also, in the case of higher agricultural consumption after segregation, subsequent study phases need to assess cross-sector linkages between the socioeconomic cost of excessive groundwater extraction and the benefits of increased agricultural GDP. Such an integrated analysis is critical to formulating a comprehensive framework for designing and evaluating rural load segregation schemes.

Qualitative and quantitative survey data from Gujarat and Rajasthan were analyzed to verify prevailing perceptions of rural load segregation. A common perception is that feeder load segregation is the only solution to guarantee a continuous electricity supply to non-agriculture connections. In reality, feeder load segregation is needed only in socio-political situations where metering of agriculture loads is not possible. Another common perception is that implementing load segregation will necessitate the creation of new feeders and added transformers. But the study findings show that existing infrastructure, which is aged and overloaded, requires augmentation irrespective of segregation. Contrary to the assumption that agricultural consumption will be restated post segregation, leading to a restatement of loss levels for transmission and distribution, the study found that estimated agricultural consumption continues to be based on earlier estimates rather than data captured from the load segregation scheme.

It is logical to assume that subsidy processes would be transparent after segregation and that loss reduction, higher revenue, and an improved load factor would ensure financial return on investment. However, the study could not establish the overall impact of load segregation on subsidy transparency owing to the lack of a system for collecting data at the feeder level (e.g., metering based on information technology [IT]). Also, the proportionate contribution of load segregation to financial return on investment could not be established.

It is generally assumed that feeder load segregation will result in improved incomes and livelihoods and better rural service standards. While the primary survey established that considerable socioeconomic development occurred over the course of implementing the schemes, their precise contribution could not be quantified. However, even if just 5 percent of increased income could be attributed to rural load segregation, the economic return would be a strong 15 percent. In terms of better rural service standards, load segregation has resulted in improved rural supply hours. But the strategy for achieving this includes various other factors (e.g., load forecasting and distribution network planning).

Other common perceptions are that feeder segregation is a one-time investment that can substitute for agriculture metering. As previously mentioned, baseline data was not collected and M&E systems were not in place during project development. As a result, it was not possible to evaluate subsequent benefits or monitor system parameters post segregation. In reality, feeder segregation is an ongoing activity that requires setting up systems to continuously monitor and enforce discipline with regard to new connections. The energy input channeled into feeders connected to agriculture consumers is available, but it also includes technical losses and consumption by unauthorized loads. Thus, metering is essential to obtain data on customer-specific consumption and implement direct subsidy-delivery mechanisms. In scenarios where consumer metering is not possible for socio-political reasons, meters can be installed at the level of the substation or distribution transformer. But to ensure commercial losses are excluded from agricultural consumption and related subsidy payments to utilities, it is important to maintain consumer indexing and have IT-enabled meters for remote data collection and automated data analysis to detect unauthorized loads.

The emerging lessons suggest that a standard approach to rural power system design using load segregation in isolation is unlikely to achieve the various states' desired outcomes. Maximizing the benefits of load segregation schemes requires accompanying institutional and governance reforms at the utility level. At most substations, feeder meters compatible with remote reading are already installed. Data from these meters needs to be automatically collected and analyzed. This will require setting up a data monitoring center dedicated exclusively to managing the data provided by the acquisition system and taking action based on that information. Operators should be trained extensively in appropriate use of the system and supported by crews responsible for field inspections in potentially irregular situations detected with support of the software.

It is vital to communicate the objective of load segregation to field staff and institutionalize a system to retain segregated feeders while releasing new connections and modifying existing ones. To manage the switching of loads between feeders in cases of breakdown, the utility should set up and institutionalize a system to track such changes and assign consumption to the appropriate feeder. Feeder segregation provides the "hardware" for a system

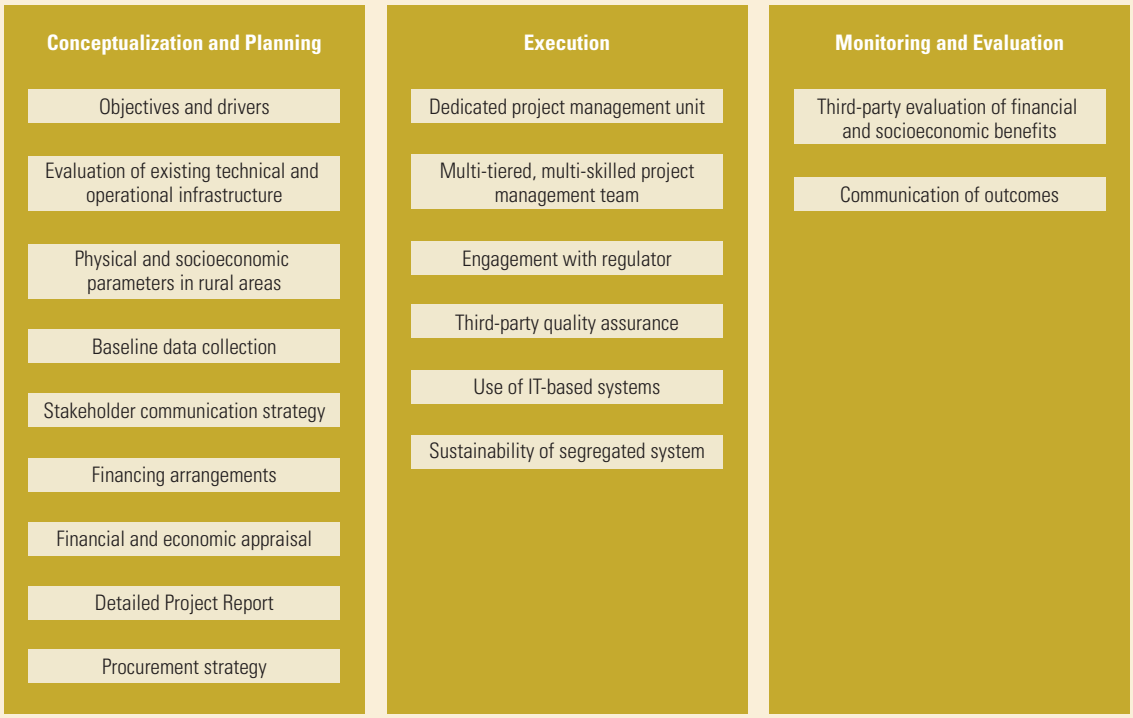
capable of delivering differentiated service to farmers and non-agricultural rural consumers, along with management decision-making tools for effective monitoring. But the eventual outcome in terms of better quality of supply and sustainable operations is a function of the necessary "software;" that is, the simultaneous and integrated application of organizational changes, accountability systems, and use of IT-based metering.

The study developed a guidance note designed to enable state governments and utilities to adopt the rural power supply approaches that best fit their on-the-ground realities. The guidance note offers the various conditions to consider, along with key issues that must be addressed at each stage of the project cycle, from conceptualization and planning through execution and M&E. During project conceptualization, decision makers must identify the strategic objective, evaluate alternative models, and decide on the best-fit solution. A decision-matrix exercise is provided to evaluate models by strategic objective and key technical and socioeconomic parameters. Planning includes preparing a robust baseline, stakeholder communication strategy, and Detailed Project Report (DPR); performing cost-benefit analyses; and adopting a suitable procurement strategy. The execution phase must ensure a multi-tiered, multi-skilled project management set-up, including a dedicated project management unit, project managers appointed for the entire project cycle, and third-party quality assurance. M&E is a dynamic process comprising regular feedback on post-implementation benefit estimates and sharing of results and experiences with key stakeholders and decision makers (figure ES.3).

This study demonstrates that there is no one-size-fits-all solution to rural power supply improvement. Project proposals should be evaluated as part of each state's broad strategic program for improving rural power supply. Given the enormous amounts of planned or already allocated investments by various Indian states, there is an urgent need to establish centralized rules of engagement outlining the principles that should underpin the design of any initiative to improve the sustainability of rural power supply while maintaining techno-economic viability.

Based on consultations with India's Ministry of Power, it was decided that a central knowledge hub should be set up to support states in undertaking rural power supply improvement programs. It was also advised that one or two states far along in implementing their feeder load segregation schemes create integrated data centers to collect and

FIGURE ES.3 PROPOSED INSTITUTIONAL FRAMEWORK FOR RURAL LOAD SEGREGATION



Source: Authors.

Note: The institutional framework can be applied to an entire state, a particular distribution utility, or even selected business units within a utility.

analyze data for such strategic purposes as ensuring transparency in determining subsidies for distribution utilities and improving operational efficiency. Furthermore, it was decided that one or two states on the threshold of undertaking rural load segregation should be selected to work with the Central Electricity Authority (CEA) on conceptualizing and designing improved rural power supply.

Setting rules of engagement and principles to ensure improved rural power supply while maintaining techno-economic viability can be achieved using a common strategic framework. If feeder load segregation emerges as the most optimal solution, it should be amenable to the direct delivery of subsidies to farmers. Improved measurement and reliability of agricultural consumption data, utilizing automated meter reading (AMR) and similar IT-based initiatives, are essential starting points that could lead to a win-win situation for all stakeholders.

The knowledge hub set up within the CEA should be responsible for developing standard documentation templates for the DPR, project management and operational manuals, technical specifications, and standard bidding documents. In addition, it should develop processes for project implementation, data management, and integrated operations to ensure sustainability of the rural power supply system. The knowledge hub can assist states that desire to follow the strategic framework with project design and implementation, including the use of AMR. **Finally, the experiences and outcomes of the demonstration projects should be widely disseminated by the knowledge hub so that lessons in success can be replicated across the country.**

1

Introduction

Subsidizing electric power for irrigated agriculture in India dates back to the advent of the Green Revolution; in the late 1960s, large government subsidies were put in place to cover the energy costs of pumping groundwater for increased irrigation to obtain higher crop yields. Decades later, those subsidies are still in place, and electricity tariffs for farmers amount to less than 10 percent of the cost of supply. Typically, farmers are charged a flat tariff rate based on the horsepower per pump rather than the level of power actually used, which is unmetered. Because feeders in villages are mixed,[1] supplying both agriculture and non-agriculture loads, the amount of power consumed cannot be disaggregated by farm or non-farm use or by the amount of power lost to technical inefficiencies or pilferage; indeed, high system transmission and distribution losses, estimated at 35 percent, basically camouflage theft.[2] The absence of metering, along with the extremely low cost of supply, means that all rural consumers lack incentives to conserve and control their power use.

Power consumption in the agriculture sector accounts for 20–45 percent of total power sale in most states in India. In some, the magnitude of the agriculture power subsidy is twice the annual budgetary expenditure on health or rural development. Empirical evidence suggests that large farmers have benefited disproportionately from the subsidy policy; most small and marginal farmers lack access to electricity, instead depending on rainfed agriculture.[3] Within an environment of chronic shortages and wasteful consumption that threatens groundwater depletion, state utilities have sought to limit the subsidy burden by restricting daily agriculture power supply to 6–8 hours, often at night. However, this practice compromises the quality and quantity of supply to non-agriculture consumers connected to the same feeder, constraining their productive economic activities.

Study Background and Objectives

The ideal power-delivery approach for rural consumers with diverse electricity needs would be a robust distribution infrastructure, with an adequate ratio of high-tension (HT) to low-tension (LT) conductors, using consumer metering based entirely on information technology (IT).[4] Such an approach is supported by studies conducted by the Planning Commission of India, which has advocated for universal metering of agricultural consumers, with subsidies limited to specified amounts of initial consumption. But under the current institutional and socio-political constraints, it is difficult to meter all agricultural connections, monitor their supply remotely, and maintain infrastructure.

One pragmatic solution tried by some states, particularly in agrarian areas, is feeder load segregation. Using either physical or virtual mechanisms to separate paid and nominally-paid feeder loads, utilities can attempt to measure and limit the amount of power supplied free to farmers for irrigation, while ensuring that non-agriculture

1. A feeder is defined as an 11-kV wire emanating from a 33-kV or higher voltage substation connecting end-user electricity consumers through distribution transformers and a low-voltage network.
2. L. Monari, "Power Subsidies," *Viewpoint* No. 244, 2 (Washington, DC: World Bank, 2002).
3. Ibid., 3.
4. Automated meter reading (AMR) technology has matured, and its cost has fallen substantially. In rural India, AMR can be effectively used as the widespread penetration of mobile networks provides a convenient communication platform for the system.

consumers receive better-quality supply for longer periods throughout the day. To date, eight states have initiated rural load segregation schemes. The earliest program was in Andhra Pradesh in 2001, followed by Gujarat, Haryana, Punjab, Karnataka, Maharashtra, Madhya Pradesh, and Rajasthan.

Against this backdrop, the World Bank, at the request of India's Ministry of Power, undertook a study of India's experience in rural load segregation in 2011–12. The study's overall goal was to draw lessons that can be applied to implementing rural feeder segregation schemes more broadly. The study's main objectives were fourfold. The first was to compare and contrast load segregation approaches from past experiences across states to draw lessons that can be applied to future programs. The second was to evaluate the financial viability of the schemes based on financial and operational parameters. Given the difficulty of conducting the assessment at the level of utilities, the subdivision level was selected as the basis for the analysis. The third objective was to gain a better understanding of the socioeconomic benefits of the schemes by conducting a primary survey of rural end-user consumers. Finally, the study aimed to develop a guidance note for policy makers that can be used to formulate a national action plan on rural feeder load segregation; the note comprises a recommended approach for developing a feasibility study and subsequent framework for the plan's design, implementation, and monitoring and evaluation (M&E).

Study Method

The study was divided into four parts, aligned with the four main objectives described above. Lessons learned from achieving first three parts formed the basis for developing the guidance note.

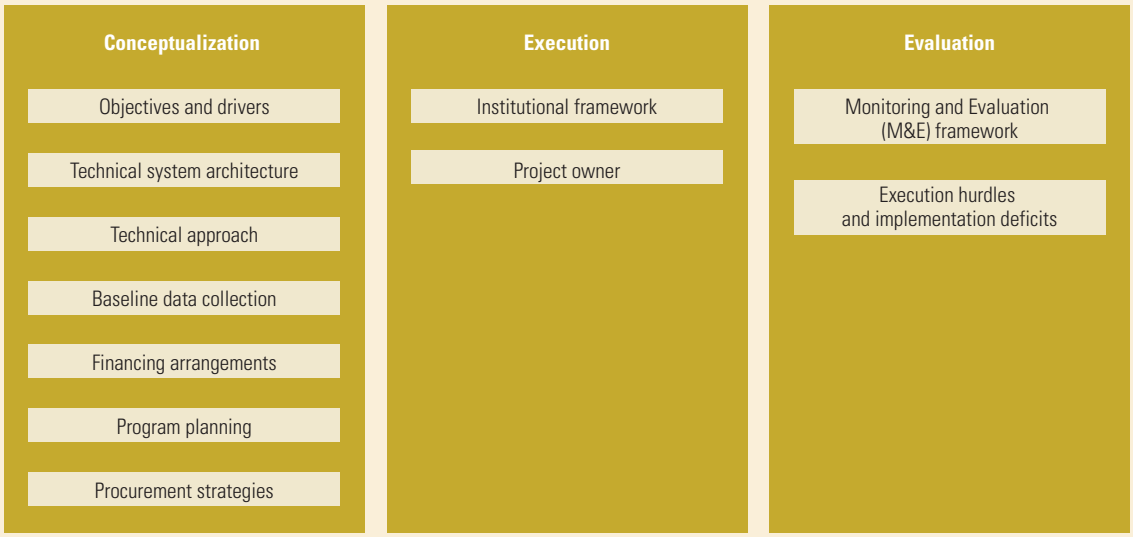
Framework for Evaluation

The findings were structured across project conceptualization, execution, and post-implementation evaluation, with frameworks also provided for financial and economic cost-benefit analyses. Figure 1.1 summarizes the framework for institutional evaluation of specific parameters across the project cycle.

Selected States for Study

Four states—Andhra Pradesh, Gujarat, Rajasthan, and Haryana—were selected for the study (box 1.1). Selection criteria included the amount of time elapsed since completion of the feeder segregation scheme, type of technical intervention used, and coverage composition. In the case of Andhra Pradesh, data collection is ongoing, and key lessons will not be finalized until analysis for all selected states has been completed. Gujarat's feeder segregation scheme was completed in 2006, while Rajasthan's program is ongoing. Though Haryana completed feeder segregation in mid-2010, only the first part of the study was applied since commenting on the scheme's

FIGURE 1.1 INSTITUTIONAL EVALUATION FRAMEWORK



Source: Authors.

BOX 1.1 PROFILE HIGHLIGHTS OF THE SELECTED STATES

In **Andhra Pradesh**, India's third largest state, agriculture accounts for more than one-quarter of state GDP. Most farmers depend on rainfed agriculture, while 28 percent of total cultivated land is irrigated. Since 2005, distribution losses have steadily declined, but subsidies and financial losses have risen. Agricultural consumers represent 14 percent of the utilities' consumer base, accounting for about one-third of sales. After virtual segregation of all mixed rural feeder loads (2001–05), the state switched to physical segregation and pilots are under way. Key objectives are to boost small rural industries by providing non-agriculture customers a 24-hour, three-phase supply and improve agricultural productivity by extending agricultural consumers' 7–9 hours of three-phase supply for pump sets.

Gujarat state in northwest India has a per-capita electricity consumption of 1,354 kWh, nearly twice the national average. In 2003, Jyoti Gram Yojna (JGY), an innovative rural electricity scheme, introduced the physical separation of 11-kV feeder lines serving rural agriculture consumers and rural household and commercial connections. The program also installed meters on feeders to eliminate theft. Since JGY was completed in 2006, agricultural energy consumption has trended upward. Today Gujarat's power distribution utility has a profitable balance sheet.

In **Rajasthan**, India's largest state in terms of land area, agriculture contributes more than one-quarter of state GDP (FY2010–11). Agriculture consumers represent just 12 percent of the utilities' consumer base but 39 percent of sales. Rural load segregation, initiated in 2005 as part of the Feeder Renovation Program, aims to reduce losses of mixed rural feeders and improve rural households' supply quality. Integrated with HVDS on agricultural feeders, DT metering, and replacement of LT cables with ABC, this ongoing program adopted virtual segregation. To eliminate agricultural theft, a roster switch on existing feeders balances three-phase, agricultural supply hours with single-phase hours when households receive an unrestricted supply. Since 2005, distribution losses have steadily declined, yet higher agricultural consumption has more than offset the financial benefit.

Haryana, located in northwest India, is among one of the most prosperous states in the country. In 2009–10, per capita income was estimated at US$1,486 (Rs. 78,781), and the literacy rate was 71.4 percent. Canals are the main source of irrigated water for cultivating diverse crops. Farmers comprise 11 percent of the electricity consumer base, accounting for 39 percent of total utility sales. Since the state government erected dedicated 11-kV feeders to separate agriculture loads from rural household connections in 2005, distribution losses have steadily declined. All of the 1,226 feeders erected were equipped with AMR compatible bulk meters. Over the same period, the utilities' financial losses have increased. Delayed completion of the scheme was resolved in mid-2010 when the state government began regular monitoring.

Detailed summaries of the state profiles are provided in the annex.

impact was considered premature. Recently, Haryana developed an M&E system at the segregated feeder level and is in the process of implementing a management information system (MIS) to enable a robust estimation of agricultural consumption (chapter 2, appendix).

To coordinate with the World Bank and facilitate data collection, the Ministry of Power appointed nodal officers in the respective states (i.e., Andhra Pradesh, Gujarat, and Rajasthan), and the World Bank hired Pricewaterhouse Coopers Private Ltd (PwC) and MRS Private Ltd to implement the activity. The staff of PwC interacted with the distribution companies and other key stakeholders to share data and first-hand experience. Throughout the study, the World Bank team consulted with the nodal officers, as well as with concerned officers at corporate-office and rural business-unit levels. For each state, one distribution utility was selected, based on the proportion of agriculture consumers served and the state's agricultural consumption. For each utility, a corresponding business unit or rural subdivision was identified for detailed evaluation of the scheme's impact (table 1.1).

To evaluate the impact of feeder load segregation on socioeconomic outcomes, MRS Private Ltd led the implementation of a primary survey of electricity consumers (table 1.2). Load segregation was carried out statewide, and it was not possible to select "with" and "without feeders" for establishing causality and quantifying impacts. Thus, characteristics of the same households were studied before and after segregation phases to determine socioeconomic changes.

TABLE 1.1 SELECTED RURAL SUBDIVISIONS AND DISTRIBUTION UTILITIES, BY STATE

State	Rural subdivision	Distribution utility
Andhra Pradesh	Warangal, Hasanparthy (mandal)	Andhra Pradesh North Power Distribution Company Ltd., Warangal
Gujarat	Vinchiya	Paschim Gujarat Vij Company Ltd, Rajkot
Rajasthan	Bassi	Jaipur Vidyut Vitran Nigam Ltd, Jaipur

Source: Authors.

TABLE 1.2 ELECTRICITY DISTRIBUTION OF SURVEYED SAMPLE

	Consumer type (number)				
State	Household	Commercial	Small industry	Agriculture	Total
Andhra Pradesh	875	313	187	625	2,000
Gujarat	417	167	83	333	1,000
Rajasthan	417	167	83	333	1,000

Source: Authors.

Structure of This Report

This report is organized as follows. Chapter 2 presents key findings from evaluating the rural feeder segregation approaches adopted by the selected states using institutional, financial, and economic frameworks for analysis. Chapter 3 summarizes perceptions and observations from the study, based on evidence from the Gujarat and Rajasthan cases, and emerging lessons. Chapter 4 provides decision makers guidance on steps to take at each stage of the project cycle for the various models considered. Finally, chapter 5 summarizes the key lessons that emerged from the study and offers recommendations on next steps.

2

Key Findings from Selected States

Experiences of the selected Indian states in implementing various approaches to rural feeder segregation were evaluated based on parameters within institutional, financial, and economic frameworks. This chapter presents the key findings that resulted from these several analyses.

Institutional Evaluation: Project-Cycle Framework

Following the criteria of the institutional evaluation framework (figure 1.1), the study collected information on the four selected states across the project cycle (table 2.1). The subsections that follow describe the key findings that emerged from the data analysis, grouped by project phase.

Conceptualization

The study found that all states shared a primary objective: ensuring supply hours to agriculture and non-agriculture rural consumers to support socioeconomic development. Other common drivers, variously prioritized by state, were ensuring rural consumers good-quality, reliable power supply; enhancing energy accounting and auditing leading to a restatement of agricultural consumption and thus loss levels; and enhancing load management through supply rotation for agriculture consumers.

The technical approach selected for feeder load segregation has been unique to each state's political thinking, regulatory policies, and state of the power sector. For example, Andhra Pradesh and Gujarat both undertook virtual segregation initially but later switched to physical segregation owing to issues of theft using phase splitters, unbalanced loads, failure of distribution transformers, and frequent interruptions due to power-system faults. To address groundwater issues, Gujarat incorporated feeder segregation into its integrated rural development program. In Haryana, where the power sector faced high distribution losses, a physical approach to load segregation was selected. Rajasthan chose a virtual scheme that became part of its feeder renovation program (FRP), which included various other system strengthening elements, including a high voltage distribution system (HVDS) on agricultural feeders, metering of distribution transformers, and replacement of low-tension, bare overhead conductors with insulated aerial bunched cables (ABC).

Because no baseline data collection and analysis was undertaken, as suggested in chapter 1, it was not possible to conduct a before-and-after analysis to evaluate the benefits resulting directly from the feeder segregation program. In terms of project cost, load segregation schemes varied across states, depending on the technical approach and system architecture used (i.e., standalone or integrated) (table 2.1). Because project scopes differed by state, direct cost comparisons were not feasible.

Execution

The study found that no specific institutional framework was set up for implementing the feeder load segregation schemes. With the exception of Rajasthan, where the circle head was designated as project manager for the FRP, the schemes were managed as part of routine business operations, with no dedicated project management units (PMUs). In Andhra Pradesh, Rajasthan, and Haryana, the states' respective distribution utilities were

TABLE 2.1 DATA HIGHLIGHTS FROM THE INSTITUTIONAL EVALUATION

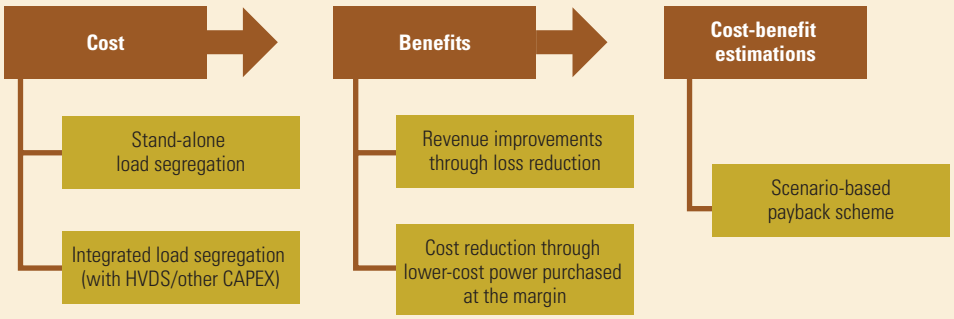
Factor	Andhra Pradesh	Gujarat	Rajasthan	Haryana
Project description				
Agricultural feeders (number)	8,878 (physical segregation)	1,904	8,126	1,226
Capital investment				
Total (Rs. billion)	3.01[a]	1.29	4.48	5.73
Per feeder (Rs. million)	3.40[a]	6.80	5.50	4.70
Per kilometer (Rs. million)	.20[a]	.23	.20[b]	.33
Conceptualization				
Technical system architecture	Stand-alone	Stand-alone	Integrated (feeder segregation, renovation, and HVDS)	Stand-alone
Segregation approach selected (investment period)	Virtual (2001–05); pilots for physical (2010–ongoing)	Virtual (prior to 2003); physical through JGY (2003–06)	Virtual on all rural mixed feeders (2005–ongoing)	Physical (2006–10)
Financing arrangements	Utilities funding pilots for physical segregation; finalization of funding for full-scale project under way.	Initially a government-local body participatory scheme but mainly funded through state-government grant.	Financial institutions (e.g., REC); Indian banks (private-sector/public-sector undertaking).	Financial institutions (REC), with 10 percent equity from state government.
Program planning	All rural feeders for pilots selected from administrative divisions (mandals) located near district headquarters; envisioned benefits not quantified in draft DPRs.	DPR not prepared; scheme estimates prepared at respective subdivision levels, and cost approved by respective divisions.	Feeder-wise DPRs prepared by in-house staff (22.7 percent IRR). Scheme initially prioritized high-loss feeders for pilot implementation, but later was extended to all rural feeders.	Subdivision-specific DPR prepared. Financial cost benefit evaluated through percentage gross returns; sample DPR studied showed 27.75 percent gross return for the scheme.
Procurement strategy	Physical segregation pilots on partial turnkey; distribution companies procure VCBs, DTs, and HT and LT conductors, while implementing contractor procures the balance.	Entire scheme initiated internally; all material procured centrally by the former Gujarat Electricity Board.	Typically on partial turnkey; distribution companies procure key materials, DTs, VCBs, and HT and XPLE conductors, while executing contractor procures the balance.	Turnkey contractor for turnkey works and in-house material management wing for labor contracts.
Execution				
Institutional framework	Pilots managed through routine business operations; specific institutional framework for complete rollout yet to be decided.	No scheme-specific framework during execution.	Circle head of respective operational areas designated as project manager; junior engineers of respective rural subdivisions designated as managers for specific sets of feeders.	Distribution company's centralized planning-and-design cell responsible for planning and awarding contract and monitoring project execution.
Project owner	Distribution utility	State government	Distribution utility	Distribution utility
Evaluation				
M&E framework		JGY cell set up at GUVNL office and project evaluation agencies selected to monitor completed and ongoing work.		M&E framework recently designed and implemented with an MIS (appendix).

Source: Authors.

a. Estimates based on DPR values.

b. Estimate based on conversion of LT length to HT at assumed LT:HT ratio of 1:0.6.

FIGURE 2.1 FINANCIAL FRAMEWORK FOR COST BENEFIT ANALYSIS



Source: Authors.

considered the project owner—defined as the entity that initiates the scheme and owns it through the implementation phase—while the state government was the project owner in the case of Gujarat.

In Andhra Pradesh, Gujarat, and Rajasthan, pilots were undertaken before initiating statewide rollout of feeder load segregation to decide on the most suitable technical approaches and evaluate consumer response. The extent to which lessons from the pilots were integrated into final project designs is unclear since pilot results were not formally documented. Although Haryana did not undertake a pilot program before initiating its segregation scheme, it conducted official field visits to Andhra Pradesh and Gujarat to gain insights from these states' experiences in load segregation. None of the schemes included IT-based metering (i.e., remote or automated meter reading) used to capture online metering data and prepare a user-friendly management information system (MIS) on measurement and control of agricultural consumption.

Evaluation

The study found that M&E of project implementation and outcomes was negligible in all states. As previously mentioned, baseline data studies had not been conducted prior to load segregation. In addition, development of an MIS tool to measure and monitor rural agricultural consumption had not been envisaged as part of the schemes. However, Gujarat undertook a post-scheme evaluation through third parties, with the Indian Institute of Management, Ahmadabad, Centre for Environmental Planning and Technology, and Institute of Rural Management, Anand appointed as project evaluation agencies. Moreover, Haryana recently designed an M&E framework to more accurately estimate agricultural consumption after segregation and establish a transparent system to determine subsidy levels for the distribution utilities (appendix).

Financial Evaluation

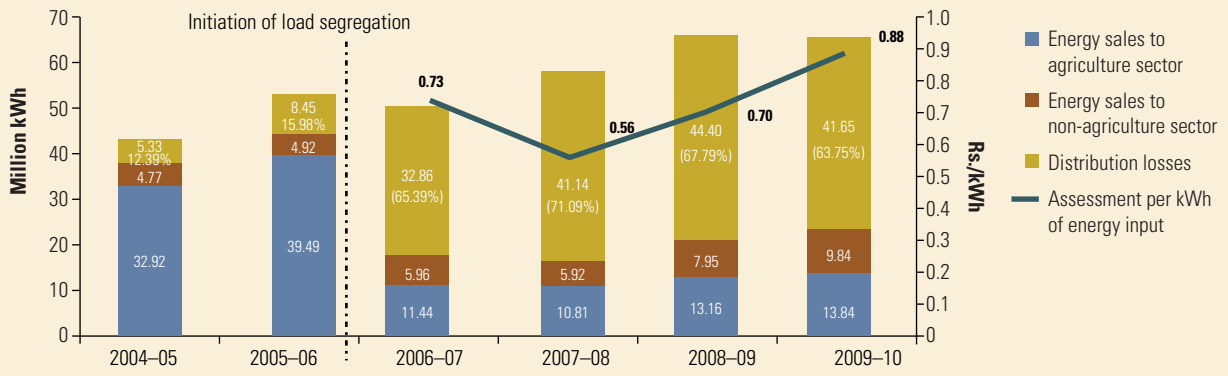
The rural load segregation scheme is expected to provide quantifiable financial returns through two main channels: (i) increased revenue accrued to the utility as a result of loss reduction and changes in the sales mix of the project area and (ii) reduced cost achieved through lower power-procurement cost at the margin. Peak load shaving resulting from more efficient management of agricultural load may also contribute to cost reduction (figure 2.1).

As previously mentioned (table 1.1), the analysis of financial benefits resulted from a detailed assessment based on data from two rural subdivisions, one from each of two states. The data was subsequently aggregated to all rural subdivisions at the level of the respective distribution utilities and finally the states.

Subdivision Findings

The two rural subdivisions selected for financial analysis were Vinchiya (Gujarat) and Bassi (Rajasthan). In Vinchiya, rural load segregation has been a critical factor in bringing transparency to agricultural consumption, resulting in accurate estimates of distribution losses. From 2006 to 2010, sales to the agriculture sector decreased by more than half of total energy input (from 75 percent to 23 percent), while distribution losses increased by nearly as much (from 16 percent to 64 percent). Revenue gain over the period can be attributed, in part, to growth in non-agriculture consumption (from 9 percent to 15 percent) (figure 2.2).

FIGURE 2.2 TRENDS OF COMMERCIAL PARAMETERS, VINCHIYA SUBDIVISION



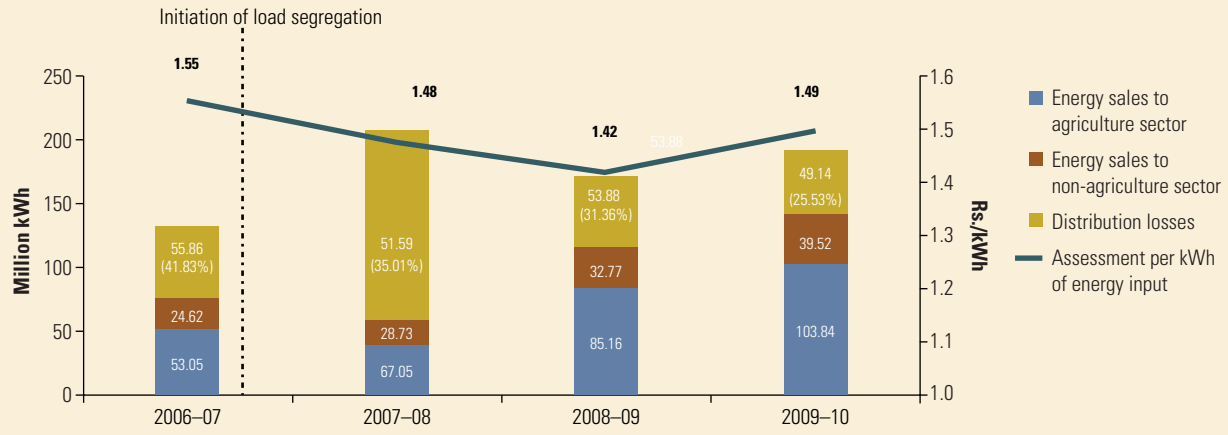
Source: Office of Executive Engineer, Rural Division, Old Power House, Rajkot.

Although Bassi did not have a significant loss restatement as in Vinchiya, the ongoing Feeder Renovation Program (FRP) has contributed significantly to reducing distribution losses (figure 2.3). Between 2006 and 2010, losses fell by nearly one-third (from 42 percent to 26 percent), but increased agricultural consumption negated the financial benefit. Most of the loss reduction occurred in the agriculture sector, where sales increased by 14 percent of total energy input (from 40 percent to 54 percent). Over the same period, non-agriculture sales grew by just 3 percent (from 18 percent to 21 percent). Higher sales to agriculture consumers reduced the annual revenue assessment per unit of energy input from Rs. 1.55 to Rs.1.49 over the period.[5]

To calculate the payback period for the subdivisions, net revenue gain (conversion of distribution losses to energy sales) was computed for the years after program completion. Incremental revenue for a given year was calculated

5. The adverse financial impact of significantly higher agricultural consumption in Rajasthan leading to higher financial losses post feeder segregation requires a detailed third-party assessment, including parallel metering of sample agricultural feeders.

FIGURE 2.3 TRENDS OF COMMERCIAL PARAMETERS, BASSI SUBDIVISION



Source: Office of Superintendent Engineer, Jaipur District Circle, Power House, Jaipur.

TABLE 2.2 PAYBACK SCENARIOS FOR VINCHIYA AND BASSI SUBDIVISIONS

Scenario (%)	Subdivision (number of years)	
	Vinchiya	Bassi
100	3	5
50	5	10
25	9	20

Source: Authors' calculations.

as the product of loss reduction in units and the average revenue assessment per unit of energy sales for the corresponding year. For Vinchiya, 71.09 percent was taken as the highest loss level, which occurred the year of program completion (FY2007–08). It was assumed that, if not for the load segregation scheme, losses would have risen further. Similarly for Bassi, it was assumed that, without the FRP, the highest loss level of 41.83 percent (FY2006–07) would have continued upward. Bassi's payback period was computed in the years post FY2008–09, the year of program completion.

The loss reduction in any year was calculated as the difference between the highest loss level (71.09 percent and 41.83 percent, respectively) and the actual loss recorded for the corresponding year. The net gain in revenue for any year was the difference between the incremental revenue and the annual operational cost, calculated at 1.5 percent of total asset value.[6] Scenario-based paybacks were calculated, assuming that net annual revenue gain was due to multiple initiatives, including load segregation. The payback ranges were 3–9 years for Vinchiya and 5–20 years for Bassi (table 2.2).

Aggregate Findings: Distribution Utility Level

Findings for the Vinchiya and Bassi subdivisions were aggregated to the level of the respective distribution utilities: Paschim Gujarat Vij Company Ltd. (PGVCL) and Jaipur District Circle. For PGVCL, the commercial parameters of 25 primary rural subdivisions were analyzed for the post-segregation period (FY2006–07 to 2010–11), and five primary rural subdivisions were selected from each operational circle. In the case of Jaipur District Circle, a purely rural circle with 21 rural subdivisions was analyzed over the same post-segregation period.

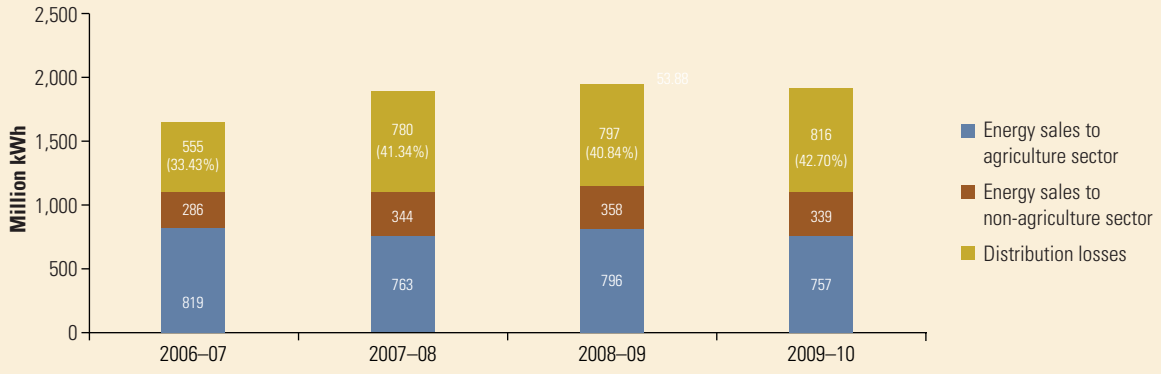
For PGVCAL, rural load segregation has been a critical factor in bringing transparency to agriculture consumption, resulting in the accurate estimation of distribution losses. Over the post-segregation period, sales to the agriculture sector decreased by 9 percent of total energy input (from 49 percent to 40 percent), while distribution losses increased by the same percentage (from 33 percent to 42 percent) (figure 2.4).[7]

For Jaipur District Circle, sales to the agriculture sector over the post-segregation period grew by about 8 percent of total energy input (from about 42 percent to 50 percent), while distribution losses fell by 16 percent (from 35 percent to 19 percent) (figure 2.5). Initial revenue gain in

6. The assumption of similar average revenue assessment is expected in a business-as-usual scenario, while in real terms, the average revenue assessment in Bassi decreased over the years due to a higher proportion of sales to agriculture consumers.

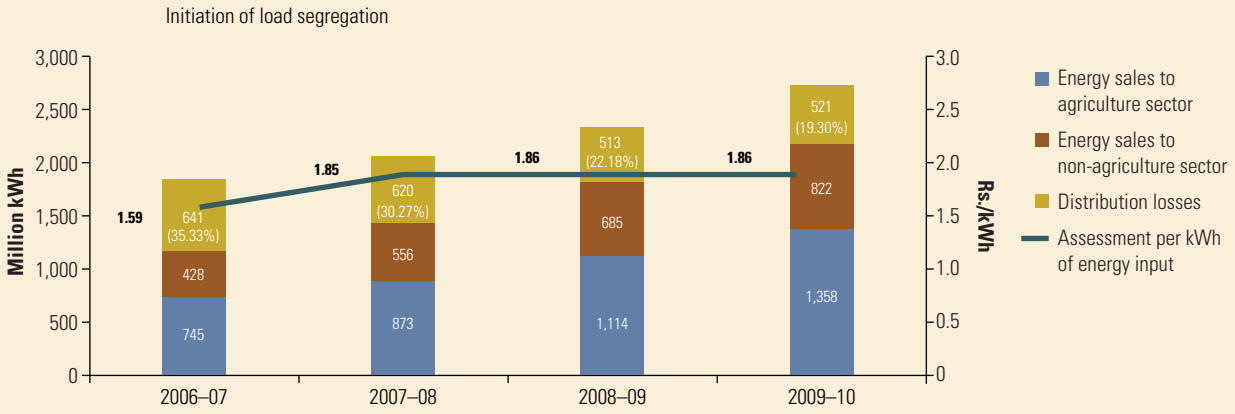
7. The per-unit revenue assessment data for the identified subdivisions had not yet been completed at the time of this writing.

FIGURE 2.4 TREND OF COMMERCIAL PARAMETERS, PGVCL RURAL SUBDIVISIONS



Source: Office of Deputy Chief Account Officer (R&C), PGVCL, Rajkot.

FIGURE 2.5 TREND OF COMMERCIAL PARAMETERS, JAIPUR DISTRICT CIRCLE



Source: Office of Superintendent Engineer, Jaipur District Circle, Power House, Jaipur.

the subdivision can be attributed to loss reduction, along with increased non-agriculture consumption, which rose by 6 percent (from 24 percent to 30 percent).

After initiating the FRP in the Jaipur District Circle, the number of both metered and unmetered agriculture connections rose consistently (table 2.3). The key reason could be the Indian government's policy to release a larger number of new agricultural connections, along with loss reductions in agricultural supply owing to the use of HVDS and ABC. For both FY 2007–08 and FY 2008–09, the number of new agriculture connections increased by more than half.

Aggregate Findings: State Level

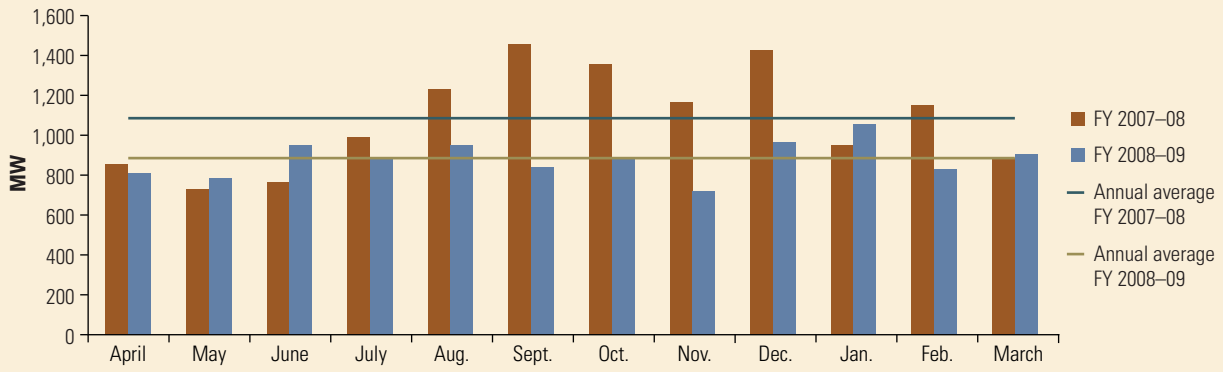
The final step of the financial analysis was to aggregate findings from PVGCL and the Jaipur District Circle to the level of the respective states. In Gujarat, the presence of mixed loads before rural feeder segregation had made it difficult for the utility to regulate agriculture power supply. The physical separation of agriculture supply from continuously supplied household and commercial connections through JGY empowered the utility to plan load rotation on agriculture-dominant feeders and improve peak demand management. In Rajasthan, virtual segregation implemented under the FRP has also resulted in rural loss reductions; however, increased sales to agriculture, along with a dwindling subsidy disbursement, has pressured the state's fiscal viability.

TABLE 2.3 TREND IN ENERGY SALES TO AGRICULTURE CONSUMERS, JAIPUR DISTRICT CIRCLE

	Energy sold to agriculture consumers (100,000)				Agriculture consumers (number)			
Fiscal year	Metered	Un-metered	Total	Added metered sales	Metered	Un-metered	Total	Metered connections added (number)
2006–07	1,966	5,483	7,449	241	42,235	53,939	96,174	3,834
2007–08	3,156	5,569	8,725	1,190	48,209	47,404	95,613	5,974
2008–09	4,637	6,501	11,138	1,480	58,343	42,956	101,299	10,134
2009–10	6,409	7,173	13,582	1,772	66,661	40,708	107,369	8,318
2010–11	6,517	6,709	13,226	108	70,580	38,971	109,551	3,919

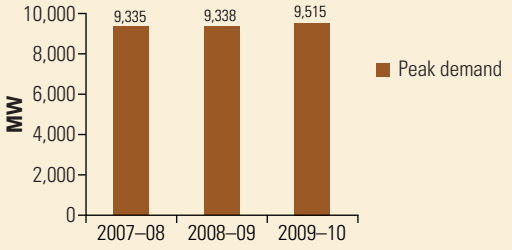
Source: Office of the Chief Accounts Officer, JVVNL, Jaipur.

FIGURE 2.6 MONTHLY AVERAGES OF MAXIMUM AND MINIMUM DEMAND, SHOWING DIFFERENCE IN ANNUAL AVERAGES, GUJARAT



Source: Gujarat State Load Dispatch Center (http://www.sldcguj.com).

FIGURE 2.7 PEAK DEMAND GROWTH



Source: Authors' calculations.

Gujarat

To better understand the impact of load segregation in Gujarat, monthly averages of the daily differences between maximum and minimum demand were plotted for FY2007–08 and 2008–09. Results showed that second half of FY2008–09 exhibited a dip in the monthly demand difference, compared to the same period the previous year, suggesting a flattening of the load curve (figure 2.6).

This analysis is also supported by the recent trend in Gujarat's energy input and peak demand growth. From FY2007–08 to 2009–10, the state registered 10.39 percent growth in energy input, compared to only 1.93 percent peak-demand growth (figure 2.7).[8] Flattening of the load curve can lead to better power-purchase planning. Indeed, the short-term power purchased by Gujarat Urja Vikas Nigam Ltd (GUVNL) declined over the same period,[9] while sale on the short-term market increased (table 2.4). The net impact has been positive, enabling GUVNL to reduce the overall cost of power purchase.

TABLE 2.4 RECENT TREND IN SHORT-TERM POWER PURCHASE AND SALE

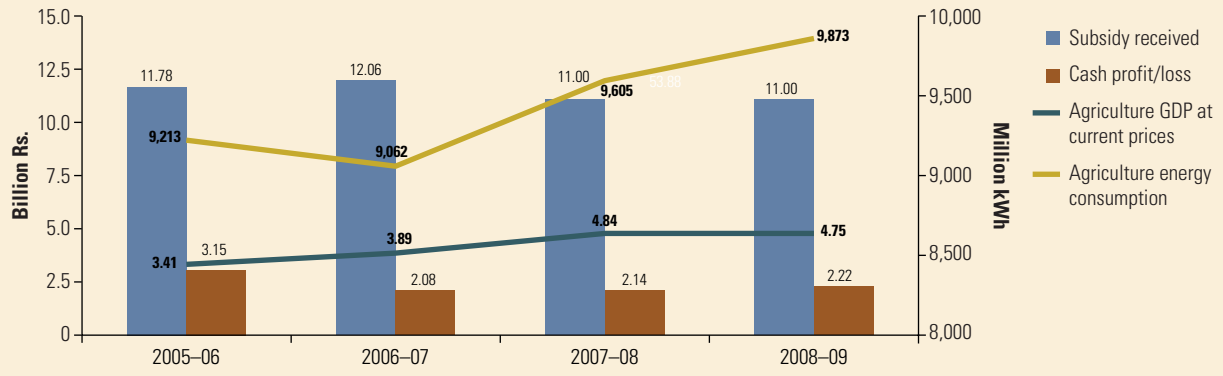
Power purchase or sale	2007–08	2008–09	2009–10
Puchase share			
Long-term (percent)	97.27	96.84	99.03
Short-term (percent)	2.73	3.16	0.97
Short-term purchase			
Million kilowatt hours[a]	1,470	1,761	580
Rs. (billion)	3.22	10.55	4.03
Rs. per unit	2.2	6	6.9
Short-term sale			
Million kilowatt hours[a]	1,595	1,328	3,604
Rs. (billion)	7.54	9.38	17.80
Rs. per unit	4.7	7.1	4.9
Net short-term purchase/sale			
Million kilowatt hours	-125	433	-3,024
Rs. (billion)	-4.33	1.16	-13.78

Source: GUVNL annual report for the respective years.
a. Includes unscheduled interchange from the grid.

8. Based on tariff orders of the Gujarat Electricity Regulatory Commission and load generation balance reports of the Gujarat State Load Dispatch Center and Central Electricity Authority for the respective years.

9. GUVNL is an electricity services holding company set up in 1999 by the former Gujarat Electricity Board as part of power-sector restructuring.

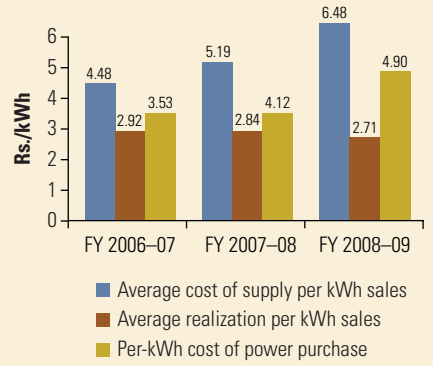
FIGURE 2.8 CASH PROFIT/LOSS AND SUBSIDY TREND, GUJARAT



Source: Power Finance Corporation performance reports, Central Statistical Organization.

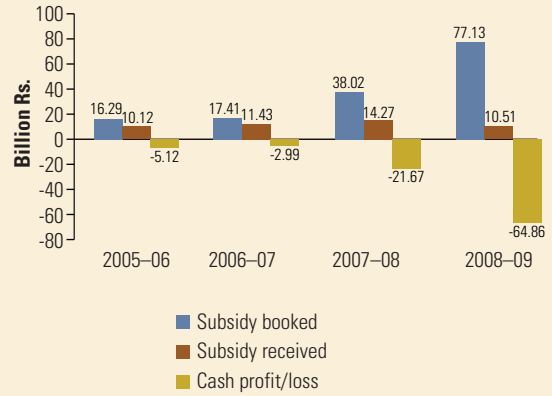
FIGURE 2.9 DRIVERS OF FINANCIAL LOSSES FOR DISTRIBUTION UTILITIES, RAJASTHAN

a. Widening Gap between Energy Cost and Revenue



Source: Audited accounts of distribution utilities, Rajasthan.

b. Diminishing Subsidy and Growing Cash Losses



Source: Power Finance Corporation performance reports, Central Statistical Organization.

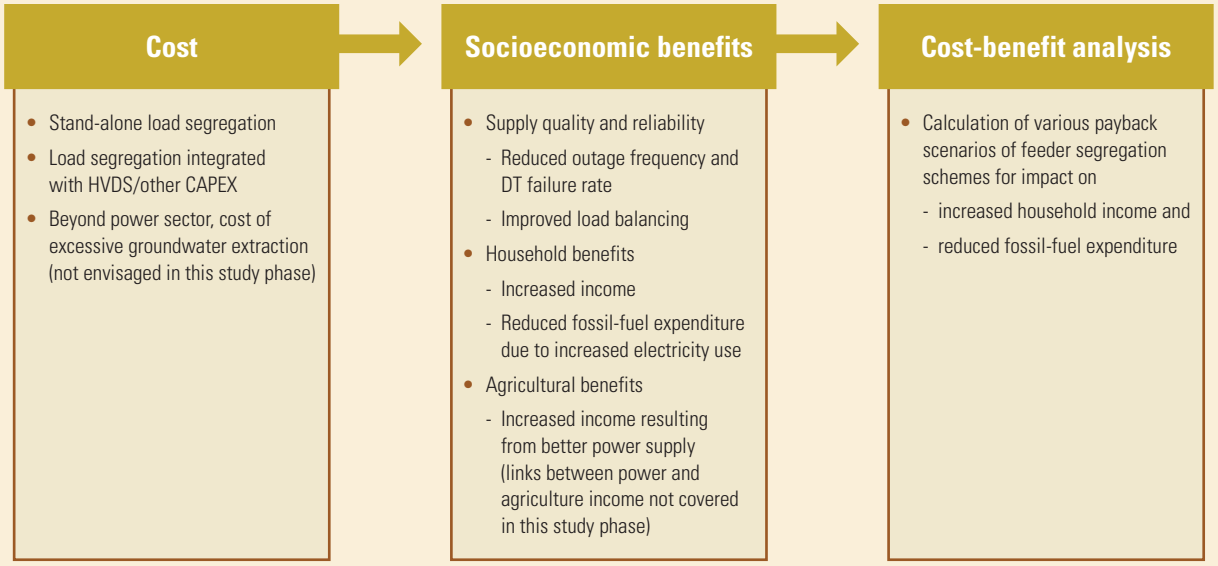
Post-segregation years have witnessed dramatic growth in agricultural energy consumption, along with a modest rise in agricultural GDP. A decline in the government power subsidy received by the agriculture sector, concomitant with rising profits of the distribution utility, have marked a positive trend (figure 2.8).

Rajasthan

Since 2005, Rajasthan has experienced substantial financial losses, which have distressed the state's overall financial position. A key factor has been the widening gap between the average cost of energy supply and revenue realization per unit of energy sales. Over a two-year period (FY2006–07 to 2008–09), the average supply cost increased by Rs. 2.0 per unit (from Rs. 4.48 to Rs. 6.48), while the average realization per unit of sales decreased by Rs. 0.21 (from Rs. 2.92 to Rs. 2.71). The increased cost of power purchase has been a primary component in the increasing cost of supply (figure 2.9a).

Other major factors that have influenced increasing financial losses are declining subsidy support from the state government and higher interest and finance charges. In FY2008–09, less than 14 percent of the total subsidy requirement was disbursed (Rs. 10.51 billion out of the required Rs. 77.13 billion), compared to about 38 percent received the previous year (figure 2.9b). From FY2006–07 to 2008–09, interest and finance charges rose by nearly 45 percent (from Rs. 7.19 billion to Rs. 16.12 billion).

FIGURE 2.10 ECONOMIC FRAMEWORK FOR COST BENEFIT ANALYSIS



Source: Authors.

Economic Evaluation

The rural feeder segregation schemes are envisaged to improve welfare outcomes through two direct channels: (i) improved quality and reliability of electricity supply and (ii) socioeconomic benefits. Better quality of supply is related to such issues as voltage, outage frequency, and data on system balancing and the failure rate of distribution transformers (DTs). Socioeconomic benefits relate to non-agriculture rural households' increased hours of electricity; these are estimated by analyzing household income and expenditure on fossil fuels in the absence of electricity (figure 2.10).

The subsections that follow discuss the welfare outcomes for the quality-of-supply and socioeconomic variables in Vinchiya (Gujarat) and Bassi (Rajasthan) subdivisions, based on findings from the 2011 survey conducted by MRS Private Ltd.

Quality of Supply

In Vinchiya, the survey findings suggest a marked improvement in quality and reliability of supply resulting from rural feeder segregation. The percentage of households reporting power outages as "rare/never" increased by more than 150 percent (figure 2.11a), while those reporting low-voltage problems decreased by about 74 percent (figure 2.11b). Similarly, the DT failure rates of the PGVCL distribution utility fell from 24.18 percent in FY2006–07 to 19.79 percent in FY2008–09.[10]

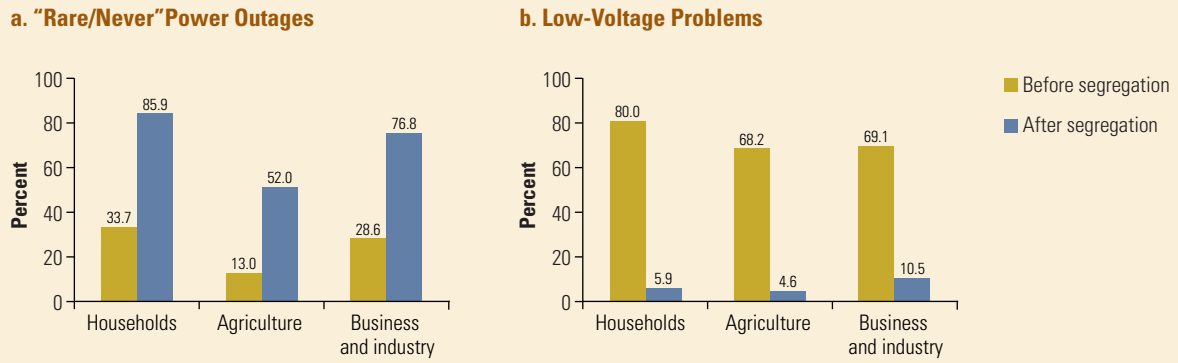
Virtual load operation on agriculture-dominated feeders using special design transformers (SDTs) was checked for system balancing. A single day's hourly loading data for all 11-kV agriculture and JGY feeders in the Vinchiya substation was collected and analyzed to determine the loading pattern during single- and three-phase feeder operations. The extent of system unbalancing was higher during single-phase, SDT operations. Typically, SDTs cater to a small proportion of single-phase load owing to physical segregation already being in place; thus, the impact of system unbalancing was found to be limited.

Post-segregation survey results in Bassi, though not as dramatic as those in Vinchiya,[11] also highlight significant reductions in supply interruptions and a marked improvement in consumer voltage profile. The percentage of households reporting power outages as "rare/never" increased nearly 34 percent (figure 2.12a), while those reporting low-voltage problems fell by more than 71 percent (figure 2.12b). Results of focus group discussions

10. According to the tariff order of the Gujarat Electricity Regulatory Commission for FY2009–10.

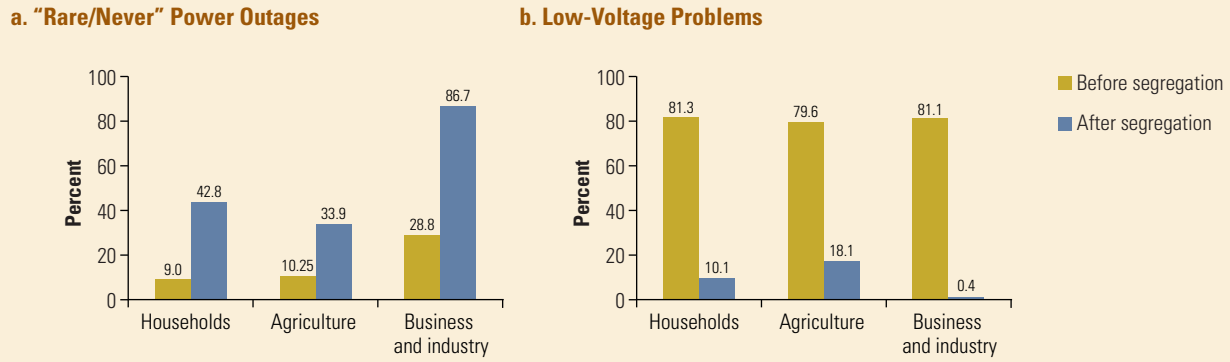
11. The comparatively better supply reliability results in Vinchiya can be attributed, in part, to Gujarat having completed its load segregation program some years earlier.

FIGURE 2.11 QUALITY-OF-SUPPLY CHANGES REPORTED BY SURVEY RESPONDENTS, VINCHIYA



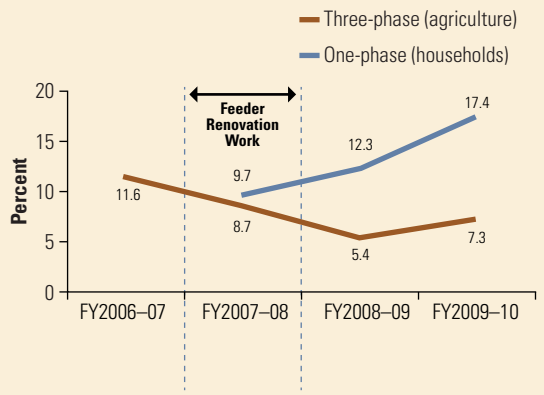
Source: MRS Private Ltd Survey 2011.

FIGURE 2.12 QUALITY-OF-SUPPLY CHANGES REPORTED BY SURVEY RESPONDENTS, BASSI



Source: MRS Private Ltd Survey 2011.

FIGURE 2.13 TREND IN DISTRIBUTION TRANSFORMER DAMAGE, BASSI



Source: Office of the Assistant Engineer, Bassi subdivision, Jaipur.

show that farmers were satisfied with scheduled power supply with minimum interruptions.

In Bassi, single-phase DTs were installed to cater to non-agriculture connections, while existing three-phase DTs supplied the agriculture load. In the first year of operation, the single-phase DTs recorded a significant damage rate, which increased in subsequent years. The reason for such high failure rates was inappropriate provisioning during the planning stage for unauthorized loads and future load growth. For the three-phase DTs, the damage rate decreased after segregation primarily because of reduced loading resulting from shifting non-agriculture load to single-phase DTs. However, the failure rate has shown signs of increasing owing to load growth and possible imbalance in some agriculture feeders due to higher currents over a sustained period of time (figure 2.13).

Socioeconomic Benefits

In Vinchiya, household income is expected to rise, owing to more time spent on income-generating activities and higher income from the sale of agricultural produce. During the post-segregation period, the average monthly household income registered an increase not entirely attributable to increased time spent on income-generating activities. For this reason, the study conducted a sensitivity analysis on various percentages of this attribution (table 2.5).

The enhanced supply hours resulting from rural load segregation will lead to an uninterrupted supply of quality power for both agriculture and non-agriculture consumers. However, supply hours will also depend on the overall availability of power from the distribution utility and the prescribed supply schedules. The enhanced supply hours will substitute for end-user consumers' existing use of fossil fuels for household lighting and diesel generators for irrigation.

It was assumed that improvements in quality of supply would increase income generation and reduce fossil-fuel expenditure in rural areas. For this reason, the benefits from quality of supply were not quantified for the economic cost-benefit analysis. The economic benefits were estimated for various scenarios based on the impact of load segregation on income generation and contribution to reduced fossil-fuel expenditure.

The economic internal rate of return (EIRR) was found to be robust across a wide range of assumptions—from 15 percent up to 55 percent (table 2.6). Estimates are based only on the subdivision level and cannot be extrapolated to the entire state.[12]

TABLE 2.5 CHANGE IN HOUSEHOLD EXPENDITURE, VINCHIYA

Parameter, monthly average (Rs.)[a]	Pre-segregation	Post-segregation
Income	4,392	5,346
Fossil-fuel expenditure	124	135
Electricity expenditure	181	209

Source: MRS Private Ltd Survey, 2011.

Note: Rural load segregation in the Vinchiya subdivision was initiated in FY2005–06, with major works concluded by FY2007–08. Midway through the project execution period (i.e., FY2006–07) is considered the base year for survey responses on pre-segregation values; all data from previous years is converted to FY2006–07 levels.

a. At constant FY2006–07 prices.

TABLE 2.6 ECONOMIC INTERNAL RATE OF RETURN FROM RURAL LOAD SEGREGATION, VINCHIYA

EIRR calculation		Contribution to income generation (percent)		
		25	10	5
Contribution to reduced fossil-fuel consumption (percent)	50	55	38	31
	25	50	32	23
	10	47	27	18
	5	46	26	15

Source: Authors' calculations.

TABLE 2.7 CHANGE IN HOUSEHOLD EXPENDITURE, BASSI

Parameter, monthly average (Rs.)[a]	Pre-segregation	Post-segregation
Income	6,667	6,802
Fossil-fuel expenditure	104	90
Electricity expenditure	222	241

Source: MRS Survey, 2011

Note: Rural load segregation in the Bassi subdivision was initiated in FY2006–07, with major works concluded by FY2008–09. Midway through the project execution period (i.e., FY2007–08) was considered the base year for survey responses on pre-segregation values; all data from previous years is converted to FY2007–08 levels.

a. At constant FY2007–08 prices.

In Bassi, the post-segregation period has exhibited an increase in time spent on income-generating activities, which has resulted in higher monthly household incomes. The average household monthly expenditure on electricity has increased, while the average expenditure on fossil fuels has decreased (table 2.7).

Since load segregation was part of the larger FRP, its estimated cost was limited to supply and installation of 11-kV double-break isolators (400 ampere) and supply and erection of single-phase DTs. The actual cost per feeder amounted to 23 percent of total program feeder cost. The same assumptions were used to extract the cost

12. The micro-level benefit estimation against reduction in DT failure rates and power-supply reliability were not considered in the EIRR calculation.

TABLE 2.8 ECONOMIC INTERNAL RATE OF RETURN FROM RURAL LOAD SEGREGATION, BASSI

EIRR calculation	Contribution to income generation (percent)			
		25	10	5
Contribution to reduced fossil-fuel consumption (percent)	50	47	43	41
	25	31	26	25
	10	19	13	11
	5	14	7	4

Source: Authors' calculation.

of virtual feeder segregation. Economic benefits were estimated for various scenarios based on the impact of load segregation on income generation and contribution to reduced fossil-fuel expenditure.

With the exception of reducing the contributions of rural load segregation to 5 percent for both fossil-fuel reduction and income generation, the EIRR calculations are robust across a range of assumptions—from 11 percent up to 47 percent (table 2.8).

As stated in the framework for economic cost-benefit analysis, these EIRRs are based on the estimated impact of power-sector supply improvement, but do not consider the cost impact of excessive groundwater extraction that may result indirectly from rural load segregation; this is likely the case in Rajasthan, where agricultural power consumption has more than offset the benefit of loss reduction. Furthermore, the current study has not determined the economic benefits of rural feeder segregation on the growth of state agricultural GDP, which would need to be analyzed as part of the M&E framework.

Summary Remarks

The financial and economic results of improved power supply in Gujarat and Rajasthan have been mixed. In the case of Gujarat, a static subsidy and limited agriculture power supply were accompanied by double-digit agricultural growth rates. By contrast, in Rajasthan, higher agricultural consumption and financial losses have not resulted in commensurate agricultural growth. To derive the maximum benefit from investments, institutional and governance reforms need to accompany technological changes. In the case of higher agricultural consumption post segregation, subsequent study phases need to assess cross-sector linkages between the socioeconomic cost of excessive groundwater extraction and the benefits of increased agricultural GDP. Such an integrated analysis is critical to formulating a comprehensive framework for the design and evaluation of rural load segregation schemes. The next chapter highlights observations on commonly held perceptions about load segregation to better inform the design and development of future programs.

Appendix: Haryana's Monitoring and Evaluation Experience

Haryana state recently designed a monitoring and evaluation (M&E) framework, implemented with a management information system (MIS). The objective was to create a system to more accurately estimate agricultural consumption following rural feeder segregation and establish transparency in determining subsidies for the distribution utilities. While the findings from this exercise reflect on-the-ground realities in Haryana, the lessons can be applied in other Indian states.

Initially, four methods were considered for estimating agricultural consumption, defined as follows (table 2.A1):

- **Feeder input:** agriculture consumption = energy input into agricultural feeders – technical losses[13] – commercial losses.[14]
- **Feeder load factor:** agriculture consumption = connected load (kW) x annual average feeder load factor x 8,760 (number of hours per year).
- **Energy audit:** agriculture consumption = unmetered consumption + metered consumption, where unmetered consumption = feeder input – technical losses – metered consumption of non-agriculture and agriculture consumers.
- **Specific consumption:** agriculture consumption = specific consumption of metered agriculture consumers (kWh per kW) x total connected load (kW).

A detailed pilot study of eight feeders was conducted to establish data availability and on-the-ground realities in the post-segregation situation. Results revealed significant variation between utility records on consumer information and actual connections; a relatively large proportion of consumers were without working meters. In addition, there was significant variation in actual connected load vis-à-vis utility records; longer hours of three-phase supply (8–14 hours) were made available. Finally, peak load was higher than connected load, indicating the presence of unauthorized load.

Given that Haryana lacks consumer indexing,[15] feeder input is clearly the most suitable method. Typically, segregated feeders are equipped with downloadable meters that can remotely transmit consumption information to data centers in corporate offices. Agricultural consumption at the feeder level can be estimated by subtracting the technical and commercial losses from the feeder energy input. However, this approach assumes a minimal non-agricultural load on these segregated feeders. Until an interface with the feeder metering system is developed and segregation is clearly differentiated between agriculture and rural household loads, feeder load factor, a less data-intensive method, can also be considered.

Development of the MIS can be customized to any of the four methods for estimating agricultural power consumption, depending on the availability of information (figure 2.A1).

The MIS depicted here is a web-based application (figure 2.A2). It can generate various reports as required by senior management of the distribution utility, regulator, or other key stakeholders (figure 2.A3).

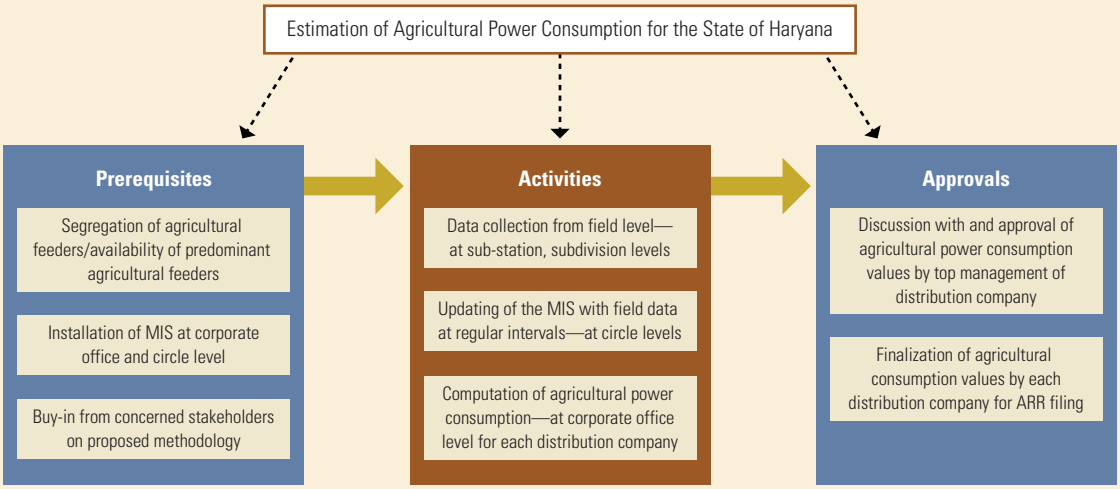
13. Technical losses were estimated by running a pilot on eight selected feeders in Haryana's two distribution utilities and simulating the load flows after determining system parameters (e.g., size and configuration of conductors and consumer details) by conducting a walk-through survey along feeder and consumer premises.
14. Commercial losses were estimated by reducing aggregate technical and commercial losses with technical losses.
15. Consumer indexing (i.e., mapping consumers and their loads to respective feeders) could have been conducted during the load segregation exercise at low incremental cost to the utility.

TABLE 2.A1 DATA REQUIREMENTS FOR AGRICULTURAL CONSUMPTION METHODS

Parameter	Feeder input	Feeder load	Energy audit	Specific consumption
Single-line diagram information	Technical losses may be computed based on a sample.	Not required.	Requires single-line diagram of the feeder.	Not required.
Consumer indexing	Not required.	Not required.	Required.	Not required.
Billing data	Not required.	Not required.	Requires billing data found to be in error.	Requires billing data found to be in error.
Estimated commercial losses	Required.	Requires a rough estimate.	Assumes system has no commercial losses.	Not required.

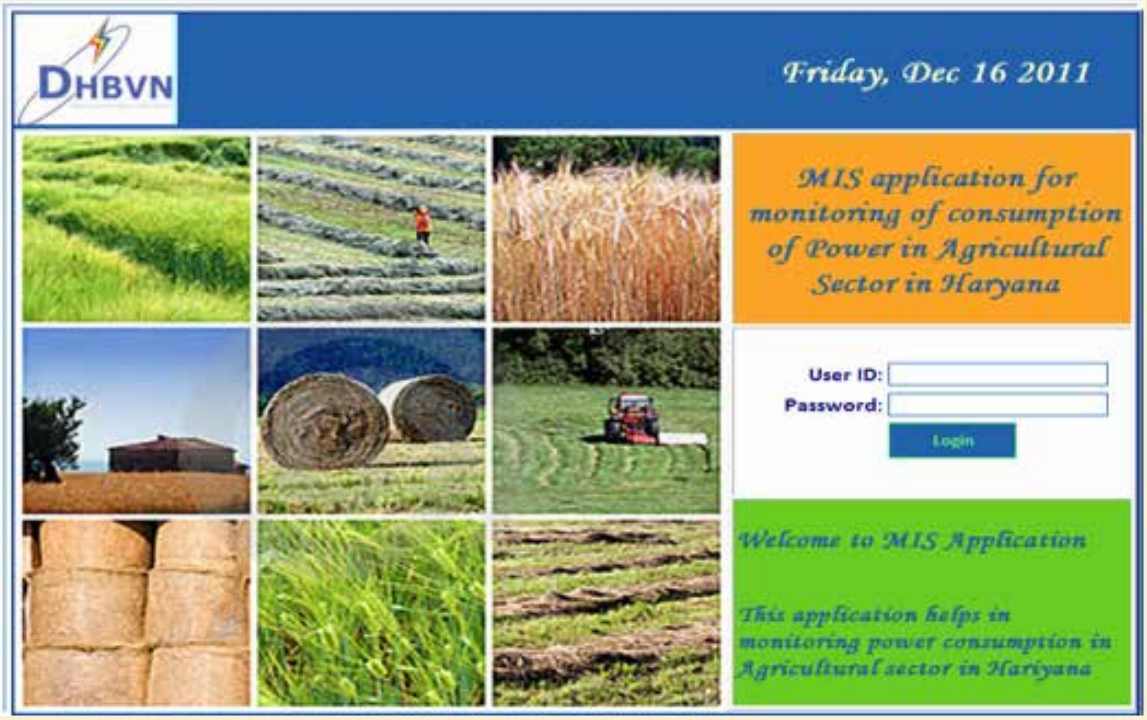
Source: Authors.

FIGURE 2.A1 IMPLEMENTING THE MANAGEMENT INFORMATION SYSTEM, HARYANA



Source: World Bank 2011.

FIGURE 2.A2 SCREENSHOT OF MIS APPLICATION, HARYANA



Source: World Bank 2011.

FIGURE 2.A3 SCREENSHOT OF MIS-GENERATED REPORT, HARYANA

Source: World Bank 2011.

3

Observations on Perceptions and Emerging Lessons

The experiences of Gujarat and Rajasthan, analyzed in the previous chapter, offer evidence of prevailing views on rural feeder load segregation schemes. Based on the quantitative and qualitative data gathered from the survey sample, this chapter offers observations on 11 commonly held perceptions and emerging lessons from the study.

Perceptions and Observations

Perception 1. Feeder load segregation is the only solution to guarantee a continuous electricity supply to non-agriculture rural connections.

Observation. Feeder load segregation—whether virtual or physical—has its associated financial and human resource requirements. It is needed only in socio-political situations where metering of agriculture loads is not possible. However, the study findings reveal cases where farmers are willing to bear the costs associated with a reliable, assured power supply. In Gujarat, for example, distribution utilities have received requests from a group of potato cultivators who are willing to pay commercial rates for increased hours of an assured supply. In such cases where metering is possible, reliable solutions based on information technology (IT) are available. One such IT-based solution is Advanced Metering Infrastructure (box 3.1).

Perception 2. Load segregation creates the need for additional infrastructure.

Observation. The common perception is that implementing load segregation creates the need for new feeders and additional transformers. However, the study findings show that existing infrastructure is aged and overloaded, requiring augmentation irrespective of segregation. At the outset, the newly segregated assets may not be optimally loaded; however, the annual 6–7 percent demand growth rate across consumer categories suggests that the infrastructure will be fully utilized within the next few

BOX 3.1 ADVANCED METERING INFRASTRUCTURE

Advanced Metering Infrastructure (AMI) can be used to limit supply hours to farmers without segregation of loads. This IT-based system uses two-way communication and back-end software applications with energy meters to measure, collect, analyze, and control energy use on a real-time or near real-time basis. It is quite effective in communicating and implementing supply rosters through remote connect/disconnect and handling detection of unauthorized consumption, thus reducing losses. The system can be designed to perform a wide range of functions. It can implement varying tariffs for consumers connected on the same feeder, including time-of-day tariffs, which can encourage farmers to switch on pump sets during off-peak hours and thus eliminate the need for remote connect/disconnect of irrigation loads. It can perform energy audits, provide utilities accurate data, and reduce billing-cycle costs. The AMI technology has matured and is now commercially available at an affordable cost.

Source: Authors.

years. Had the infrastructure been robust and optimal initially, the requirements would have been limited to a simple reorganization of loads with the addition of a few new feeders.

Perception 3. Agricultural consumption will be restated post segregation, leading to a restatement of loss levels for transmission and distribution.

Observation. Contrary to the common perception, the study findings show that estimated agricultural consumption is not based on data captured from the rural load segregation program. In the case of Gujarat, accounting for agricultural consumption improved at the subdivision level after segregation. But at the state level, agricultural consumption in utility and regulatory accounts—even five years after program completion—is based on earlier estimates. Similarly, in Rajasthan, where agricultural consumption increased post segregation at the level of the distribution utility, agricultural consumption for both utility and regulatory accounts continues to be based on prior estimates.

Perception 4. The booking, allocation, and delivery of subsidies post segregation will be a transparent process that earmarks agriculture supply.

Observation. The overall impact of load segregation on agriculture subsidies could not be established by this study owing to the lack of an agreed system with the regulator for feeder data collection. In Gujarat, the state government allocates a fixed subsidy for agriculture supply; however, in Rajasthan, as well as Andhra Pradesh and Haryana, subsidy booking and allocation have exhibited a rising trend (annex).

Perception 5. Financial return on investments in load segregation is possible through loss reduction, increased revenue, and an improved load factor.

Observation. In Gujarat, the strengthening of agriculture accounting led to loss restatement and subsequent loss reductions at the subdivision level (Vinchiya). Following segregation, revenue assessment and peak-load management improved, but the proportionate contribution of the JGY scheme could not be established. In Rajasthan, the FRP resulted in loss reduction; however, a corresponding increase in agricultural consumption at the level of the Bassi subdivision and distribution utility have resulted in greater financial distress.

Perception 6. Feeder load segregation schemes result in socioeconomic benefits in rural areas through improved livelihoods and income and better health and educational outcomes.

Observation. The primary survey established that considerable socioeconomic development occurred over the period of the respective rural load segregation schemes, although their precise contributions could not be quantified. However, if just a 5 percent increase in income could be attributed to rural load segregation, the economic return would be a strong 15 percent. Although the link between the power subsidy and agricultural growth is beyond the scope of this study, it is interesting to compare results in the cases analyzed. Over the past five years, Gujarat has experienced double-digit agricultural growth at the macro-level despite limited subsidy and power supply. By contrast, Rajasthan's increased agricultural consumption and consequent higher financial losses have failed to translate into commensurate growth in the state's agricultural GDP.

Perception 7. Load segregation will lead to better rural service standards.

Observation. Load segregation has resulted in improved supply hours in rural areas. However, the strategy for supplying better-quality power in rural areas should also include load forecasting and distribution network planning, including a needs assessment for HVDS to ensure that the HT:LT ratio is within the norm. Supply expansion should also take the availability of generation capacity into account.

Perception 8. Investments are based on baseline data of agricultural consumption, and monitoring and evaluation systems have been put in place.

Observation. Baseline data on such factors as existing loss levels, agriculture consumption, connected load, number of consumers, and number of functional feeders was not collected. Moreover, monitoring and evaluation (M&E) systems were not put in place during project development. As a result, it was not possible to monitor system parameters post segregation or evaluate subsequent benefits. Remote metering systems are not in place to capture detailed data on 11-kV feeders, even years after completion of physical work.

Perception 9. Feeder segregation is a one-time investment.

Observation. In reality, feeder segregation is an ongoing activity requiring the setting up of systems to continuously monitor and enforce discipline with regard to new connections; otherwise, one runs the risk that segregated agriculture feeders will be reconverted into non-agriculture ones within a few years time. During execution of the rural segregation scheme in Gujarat, farmers residing in farmhouses demanded power supply along the pattern of rural non-agriculture consumers. In response, special design transformers were introduced on agriculture-dominant feeders to provide single-phase supply when three-phase supply for agriculture was switched off.[16] In Haryana, connections had to be provided from agriculture feeders to one-room tenets, known as "dhanis," and, in some cases, large farmhouses in agricultural fields. All utilities must deal systemically with similar demands, which may occasionally arise.

Perception 10. Feeder segregation is a viable substitute for agriculture metering.

Observation. For segregated feeder systems, meters are generally provided at the substation level, and the amount of energy channeled into feeders connected predominantly to agriculture consumers is available. But this energy input also includes technical losses and consumption by unauthorized loads. While technical losses can be calculated, there is no way to estimate commercial losses since most utilities lack robust energy audit systems and operational practices to handle changes in connected loads. Metering of agriculture consumers is essential to obtain data on customer-specific consumption and subsequently implement direct subsidy-delivery mechanisms. But metering alone may not lead to a 24-hour supply for non-agriculture consumers unless farmers are willing to pay cost-reflective rates for consumption beyond their allocated quota. Unless supported by an effective M&E system, feeder segregation is a necessary but insufficient tool for ensuring transparent subsidy allocation to farmers.

16. Based on information provided by the Office of the Managing Director, GUVNL.

Perception 11. Without customer metering, IT-based tools are not useful for measuring and monitoring power consumption.

Observation. When consumer metering is not possible, meters can be installed at the substation or DT level. In the case of virtual segregation, meters installed at feeder take-off points at substations record time-stamped energy consumption, providing data on agricultural consumption.[17] In the case of physical segregation, feeder-level energy input directly estimates agricultural consumption. But to ensure that commercial losses (i.e., unauthorized and under-reported loads) are excluded from agricultural consumption and related subsidy payments to utilities, it is important to implement consumer indexing and institutionalize a system for its continuous updating when new consumer profiles are added and existing ones are revised.[18]

Currently, most distribution utilities implement enterprise resource planning (ERP) systems, along with a restructured-accelerated power development reform program (R-APDRP). In an ERP environment, it is fairly simple to implement solutions that automatically update system parameters when loads are changed and perform energy audits to generate risk flags whenever a mismatch between a connected load and energy consumption occurs. Even without these systems, implementing an IT-based solution on feeder meters with consumer indexing in place is a powerful tool for monitoring and evaluating agriculture consumption in the absence of consumer metering.[19] Yet ensuring that the information generated is acted upon requires supporting institutional and governance reforms at the level of the utility.

17. Metering data can be correlated with the agriculture supply schedule to estimate agricultural consumption; it can also be used to detect unauthorized system loads by comparing connected loads with actual consumption.

18. Consumer indexing refers to mapping consumers to specific feeders and maintaining an updated record of consumer loads; this system works successfully when integrated across commercial (new connections and billing) and operations departments.

19. IT-based metering (e.g., advanced metering infrastructure or remote meter reading) can automatically capture meter data, transfer it to centrally located servers that analyze it and generate reports for both strategic and operational use, prepare consumer bills, and help perform energy audits (box 3.1). These systems can also be designed to remotely connect/disconnect loads. Most importantly, automated meter reading provides accurate and regular data that can be used for operational and strategic planning, without placing added burden on the utility's typically scarce manpower resources.

Emerging Lessons

The evidence presented in this chapter suggests that a standard approach to rural power supply involving rural load segregation alone is unlikely to meet the states' various strategic objectives. As mentioned above, maximizing the benefits of load segregation schemes requires accompanying institutional and governance reforms at the utility level. At most substations, feeder meters compatible with remote reading are already installed. Data from these meters needs to be automatically collected and analyzed. This will require setting up a data monitoring center dedicated exclusively to managing the information provided by the acquisition system and taking action based on it. Operators should be trained extensively in appropriate use of the system and supported by crews responsible for field inspections in potentially irregular situations detected with support of the software.

It is also critical to communicate the objective of the load segregation exercise to field staff and institutionalize a system to retain segregated feeders while releasing new connections and modifying existing ones. To manage the switching of loads between feeders in cases of breakdown, the utility should set up and institutionalize a system to track such changes and assign consumption to the appropriate feeder. Feeder segregation provides the "hardware" for a system capable of delivering differentiated service to farmers and non-agricultural rural consumers, along with management decision-making tools for effective monitoring. But the eventual outcome in terms of better quality of supply and sustainable operations is a function of the necessary "software;" that is, the simultaneous and integrated application of organizational changes, accountability systems, and use of information technology.

4

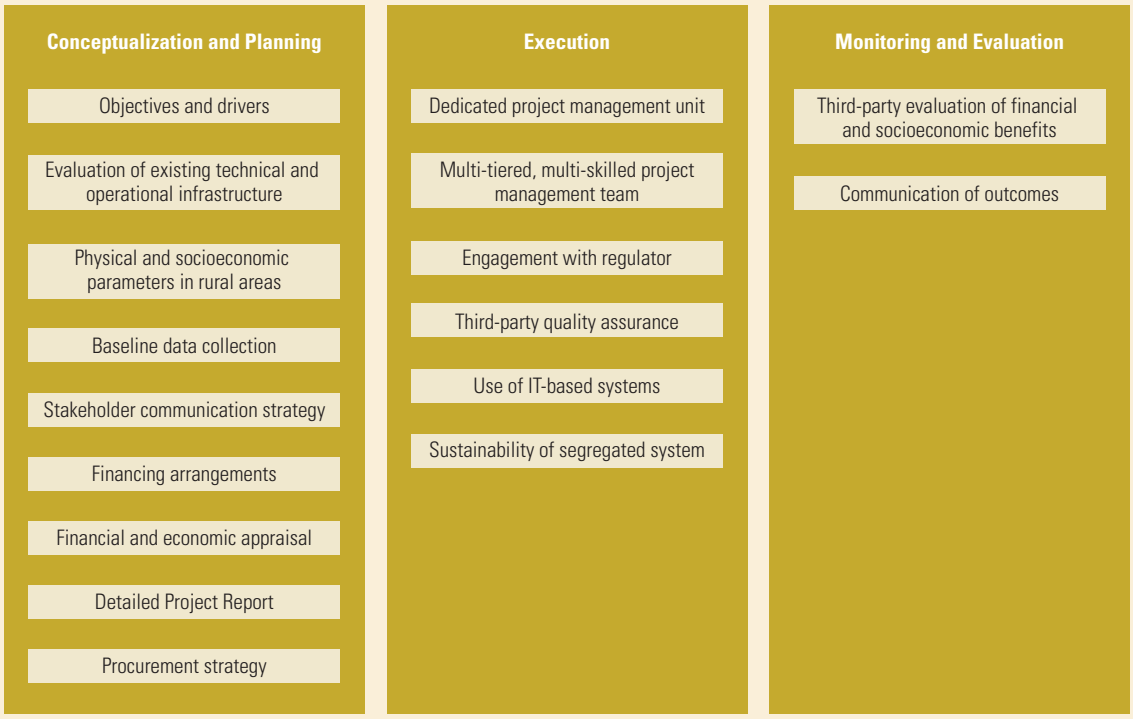
Toward Sustainable Models: Guidance Note

Following Gujarat's relatively successful Jyoti Gram Yojana (JGY) program, various other Indian states have initiated or re-started rural load segregation programs. To enable decision makers to adopt the approaches that best fit their states' on-the-ground realities, this chapter offers state governments and distribution utilities a guidance note on the various feeder segregation models to consider, along with key issues that must be addressed at each stage of the project cycle to ensure the development of a sustainable rural power supply system.

Institutional Framework

The proposed institutional framework for rural load segregation covers the entire project cycle, from conceptualization and planning through execution and monitoring and evaluation (M&E) (figure 4.1).

FIGURE 4.1 PROPOSED INSTITUTIONAL FRAMEWORK FOR RURAL LOAD SEGREGATION



Source: Authors.

Note: The institutional framework can be applied to an entire state, a particular distribution utility, or even selected business units within a utility.

Conceptualization and Planning

Conceptualization

During the conceptual phase of the rural load segregation scheme, decision makers must:

- Identify the strategic objective of load segregation.
- Evaluate alternative models to achieve the strategic objective.
- If load segregation is selected as the most viable option, decide on the best-fit model based on the strategic objective and analysis of state-specific parameters.

Identify the strategic objective. As previously discussed, the strategic objective of load segregation can vary widely, ranging from socioeconomic development of rural areas to achieving loss reduction and enhanced transparency in estimating agriculture consumption. States may also be interested in improving non-agriculture consumers' supply quality and reliability or enhancing agriculture consumers' supply quality and quantity by creating additional network capacity and improving network infrastructure. While most states are interested in all of these objectives, prioritization will likely differ by state. For example, in Haryana, loss reduction was the primary objective of load segregation; Rajasthan's main objective was strengthening power-supply infrastructure for farmers, while Gujarat desired that rural household connections have power supplied 24 hours a day.

Evaluate alternative models. Given that load segregation is capital intensive, alternative models to achieve the strategic objective should be evaluated. For example, if the strategic objective is limited to loss reduction, a more effective option may be strengthening energy audit practices and performance accountability in the field, along with using an IT-based system to prepare an MIS. If consumer metering is possible or if DTs are dedicated to rural loads, IT-based metering (i.e., AMI) at the consumer or DT level can be an effective way to implement supply rosters, measure consumption, and thus accurately estimate system losses without undertaking load segregation (box 3.1).

Decide on the best-fit model. If load segregation is found to be the most viable option, a best-fit model will need to be selected based on the strategic objective and analysis of state-specific parameters of existing technical and operational infrastructure and the physical and socioeconomic status in rural areas.

Currently, five load-segregation models are prevalent in India. These are physical segregation of consumers connected to the rural distribution network with or without high voltage distribution system (HVDS) integration, virtual segregation of consumers using logical controls at the grid substation with or without HVDS integration, and mixed feeder with IT-based metering initiatives; the latter model can be used with any of the other four options for transparent measurement of consumption and effective load management. The study conducted a decision-matrix exercise that separately mapped the strategic objectives and the two sets of state-specific parameters against the five load-segregation models. The results of the exercise are presented below.

Best-Fit Models by Strategic Objective

Table 4.1 presents the decision matrix for selecting the best-fit load segregation model available to the distribution utility by strategic objective. After obtaining a set of "high," "medium," and "low" results against the applicable objectives, the utility can decide on the best fit.

In terms of loss reduction, physical segregation with HVDS is the most suitable model since it reduces the LT network and enables agricultural metering using DTs. Virtual segregation without HVDS, which provides only minimal reduction in the LT network and no assistance in metering agricultural consumption, is the least suitable option. The remaining models are moderately suitable when weighed against the loss-reduction objective.

If the strategic objective is ensuring transparency in agricultural consumption and determining subsidy levels, physical segregation with or without HVDS is highly suitable if appropriate systems are set up within the utility to regularly collect and analyze the energy flow data from segregated feeders. IT-based AMI systems, equipped with automated data collection and analysis functions, are highly suited to accurately calculating agricultural consumption and subsidy estimates. In fact, IT-based solutions enable regulators and other external stakeholders to access consumption data on a real-time basis. Virtual load segregation models are moderately suitable owing to limitations in agriculture metering of end-user consumers, even after segregation.

For supply-related objectives, physical segregation models and IT-based AMI are quite a good fit since they enable load management on both agriculture and non-agriculture connections. Virtual segregation models, which have all rural consumers on the same network, are only moderately suitable owing their extensive load management requirements.

TABLE 4.1 DECISION MATRIX FOR STRATEGIC OBJECTIVES

Strategic objective	Virtual segregation		Physical segregation		Mixed feeder with IT-based AMI with remote meter reading and connect/disconnect
	Without HVDS	With HVDS	Without HVDS	With HVDS	
Loss reduction	Low	Medium	Medium	High	Medium
Transparency in agriculture consumption and subsidy	Medium	Medium	High	High	High
Continuous, 24-hour supply to non-agriculture consumers	Medium	Medium	High	High	High
Quality and quantity of supply to agriculture consumers	Medium	High	Medium	High	Low

Source: Authors.

Note: "High" = most suitable; "Medium" = moderately suitable; "Low" = least suitable.

If the objective is ensuring agriculture consumers quality and quantity of supply, releasing pending agriculture connections and planning for future ones would require creating additional distribution infrastructure. HVDS-based load segregation models, whether virtual or physical, provide the added infrastructure required and thus are the best fit, followed by virtual or physical load segregation without HVDS. IT-based AMI creates no additional infrastructure and thus is the least suitable choice.

Evaluating Existing Technical and Operational Infrastructure

Table 4.2 presents the decision matrix for evaluating the five segregation models against the existing technical and operational infrastructure constraints of the distribution utility. After obtaining a set of "high," "medium," and "low" results against the applicable parameters, the utility in question can decide on the most techno-economically feasible solution.

States with a large proportion of LT networks are susceptible to higher technical losses and power pilferage. Both physical and virtual segregation models with HVDS provide for a higher HT:LT ratio and thus are the best fit. An IT-based AMI solution is least suitable since it fails to provide for any change in network structure. The virtual and physical segregation models without HVDS are moderately suitable for this business scenario.

For states with a high proportion of unmetered agricultural consumption, it is essential to create a segregated network that can support agriculture metering. Physical segregation models with or without HVDS and virtual segregation with HVDS make it possible to provide for dedicated metering infrastructure for agriculture connections. By contrast, IT-based AMI on unmetered agriculture connections may pose implementation complexities owing to consumer discontent with direct metering; thus, this option is the least suitable. That said, implementing some type of IT-based solution to automatically collect and analyze energy data at the substation level would be useful.

If the state distribution utilities have suffered significant financial losses in recent years, it would not be feasible to implement capital-intensive projects. The best option would be direct agriculture metering through IT-based AMI, followed by virtual load segregation without HVDS. The other three models score low against this business scenario.

For a business scenario with high AT&C losses, the distribution utility would require a metering infrastructure to accurately measure losses in the rural and agricultural networks. The best-fit options are agriculture metering using IT-based AMI or DT metering using HVDS. While physical segregation without HVDS would segregate the agriculture distribution network, it would provide for consolidated metering of agricultural consumption; thus, this option is a moderately good fit. Virtual segregation without load segregation is the least suitable option since it does not support agriculture metering.

States with inadequate power supply to meet electricity demand would be unable to maximize benefits from load segregation; thus, the most suitable models are IT-based AMI and virtual segregation without HVDS. Physical load segregation models have the lowest applicability since they would incur high capital costs but would be unable to attain the benefits of continuous power supply to non-agriculture consumers.

Control of agriculture supply hours helps to regulate groundwater usage. If the state distribution utility has the necessary skills set and consumer acceptability to control the supply hours for agriculture connections, then physical load segregation models and IT-based AMI are the best choices since they enable improved control of agriculture supply. Virtual segregation models are moderately suitable owing to their comparatively lower load management capability.

For states that exclude agriculture load from peak load management, load segregation can achieve the same benefits. Based on the operational ease of peak load management, the physical segregation models and IT-based AMI are the most suitable options, while virtual segregation without HVDS is the least suitable.

Evaluating Physical and Socioeconomic Status

Table 4.3 presents the decision matrix for evaluating the five segregation models against the physical characteristics and socioeconomic status of the rural areas considered.

For states with a large geographical spread, segregation would entail a rural distribution network of significant length, requiring large capital expenditure. Given its cost-effectiveness, IT-based AMI would be the best-fit solution, followed by virtual segregation with HVDS as a medium fit. Because of the added infrastructure that may be required, physical segregation is the least suitable option. Though virtual segregation without HVDS may not require added infrastructure, it would have little effect on supply quality and load management and thus is ranked low.

Rural load segregation is expected to result in increased agricultural consumption owing to improved supply hours and release of pending connections. In such a scenario, a limited agriculture subsidy would place added financial burden on the state distribution utility; thus, IT-based AMI would be the best fit since it would not support increased agricultural consumption. Physical segregation models are least appropriate, while virtual segregation models are moderately suitable, depending on the potential for increased agricultural consumption following segregation.

For rural areas with low levels of customer service, HVDS-based load segregation models are the most suitable options, given their ability to improve supply quality. Based on this criterion, segregation models without HVDS are a moderately good fit, while IT-based AMI is ranked low.

If states require intensive communication with farmers before initiating rural schemes, the best options are physical segregation models, which entail such communication. Virtual segregation models are a moderately good fit, while IT-based AMI is least suitable.

TABLE 4.2 DECISION MATRIX FOR EXISTING TECHNICAL AND OPERATIONAL INFRASTRUCTURE

Business scenario of technical and operational infrastructure	Virtual segregation		Physical segregation		Mixed feeder with IT-based AMI with remote meter reading and connect/disconnect
	Without HVDS	With HVDS	Without HVDS	With HVDS	
Low HT:LT ratio	Medium	High	Medium	High	Low
Low metering of agriculture sales	Medium	High	High	High	Low
High financial losses in utility	Medium	Low	Low	Low	High
High AT&C losses	Low	High	Medium	High	High
Inadequate power supply	High	Medium	Low	Low	High
Ability to control supply hours to agriculture consumers (with groundwater implications)	Medium	Medium	High	High	High
Wide scope for peak load management	Low	Medium	High	High	High

Source: Authors.

Note: "High" = most suitable; "Medium" = moderately suitable; "Low" = least suitable.

TABLE 4.3 DECISION MATRIX FOR PHYSICAL AND SOCIOECONOMIC PARAMETERS

Business scenario of physical, social, and economic parameters	Virtual segregation		Physical segregation		Mixed feeder with IT-based AMI with remote meter reading and connect/disconnect
	Without HVDS	With HVDS	Without HVDS	With HVDS	
Large geographical spread	Low	Medium	Low	Low	High
Large number of agriculture connections with limited subsidy	Medium	Medium	Low	Low	High
Low customer service levels in rural areas	Medium	High	Medium	High	Low
Intensive communication with farmers	Medium	Medium	High	High	Low

Source: Authors.

Note: "High" = most suitable; "Medium" = moderately suitable; "Low" = least suitable.

Remarks

This decision-matrix exercise has considered the three sets of parameters in isolation; yet in reality, most are interlinked. In practice, states and distribution utilities should identify the most critical parameters for their unique situations and utilize the results of the exercise. Ultimately, they will need to review all of the relevant parameters as a whole before deciding on the best-fit load segregation model.

Planning

Planning the design and implementation of the rural segregation scheme includes the following key steps:

- Prepare a robust baseline.
- Develop a stakeholder communication strategy.
- Decide on financing arrangements.
- Undertake financial and economic cost benefit analyses.
- Prepare a Detailed Project Report (DPR).
- Adopt an appropriate procurement strategy.

Prepare a robust baseline. The proposed project requires a robust baseline of technical, financial, and economic parameters (e.g., consumer profile, consumption pattern, collection efficiency, hours or supply, and loss levels) through a third-party assessment. So that project targets can be set and benefits evaluated, the baseline parameters should be monitored from the scheme's conceptualization phase through evaluation. If the utility has chosen to implement physical load segregation, consumer indexing can also be conducted with low incremental cost to the utility.

Develop a stakeholder communication strategy. The communication strategy should aim at identifying appropriate target audiences (e.g., public authorities, lending agencies, regulators, and consumer representatives) and requisite communication channels, ranging from public media to direct presentations. It is critical that a consultative forum be used by the distribution utility to inform key stakeholder groups (e.g., regulators, consumers, and village administrative bodies [panchayats]) about the project's rationale and benefits. The consultative forum can be used to inform consumers about the cost of the segregation scheme and help them to appreciate the value of national resources deployed for irrigation. The forum can also be used to obtain consumer feedback to develop an optimum project design. This approach can inculcate a sense of ownership among stakeholders and thus ensure the project's success.

Decide on financing arrangements. Prior to project implementation, it is important to decide on the financing arrangements. For example, given a project's potential socioeconomic benefits, the state government may decide to contribute all or part of the required funding.

Undertake financial and economic cost benefit analyses. Financial benefits, calculated against system costs, include increased revenue from loss reduction and reduction in power purchase cost through peak load reduction (figure 2.1). The payback period or internal rate of return (IRR) should be calculated accordingly. Economic benefits, calculated against power-sector costs and water-sector extraction, include improved quality of power supply through reduced outage and improved voltage, increased household income, and higher agricultural output (figure 2.10); ancillary socioeconomic benefits resulting from

increased hours of rural non-agricultural supply include better health and educational outcomes and increased employment opportunities in villages.

Prepare a Detailed Project Report (DPR). All analyses should be captured in a streamlined, standardized DPR template. The DPR should include the baseline data, expected project outcomes, financing plan, financial and economic appraisals of the investment, implementation arrangements, stakeholder communication strategy, and monitoring and evaluation (M&E) framework.

Adopt an appropriate procurement strategy. The strategy selected by the implementing distribution utility depends on the mode of execution (e.g., in-house; turnkey engineering, procurement, and contracting [EPC]; or more evolved public private partnership [PPP] mechanisms that outsource system operation and maintenance). Deciding on in-house execution should take into account the utility's past experience in materials procurement. Similarly, deciding to partially or fully outsource on a turnkey basis should consider past performance of the prospective turnkey contractors in the project implementation area; turnkey EPC is recommended since it would ensure participation of reputed industry players, leading, in turn, to implementation efficiency and quality assurance. If the utility decides to procure materials separately, third-party quality-assurance agencies should be engaged to conduct inspections.

Execution

Subsequent to project conceptualization and planning is field-level implementation. The key steps that comprise the scheme's execution phase are as follows:

- Ensure a multi-tiered, multi-skilled project management organization, including a dedicated project management unit (PMU), project managers appointed for the entire project cycle, and third-party quality assurance.[20]
- Institutionalize the principles of load segregation.
- Ensure regulatory acceptance.
- Use IT-based solutions.

Ensure a multi-tiered, multi-skilled project management set-up. At the corporate level, this means setting up a specialized cell responsible for centralized project monitoring and taking requisite corrective and preventive measures, institutionalizing a review system of senior management or state government, and facilitating experience-sharing between the PMUs. At the middle-management level, a cross-functional team should be set up. At the field level, dedicated PMUs with technical and management expertise should be established to ensure effective project implementation. The PMUs are responsible for contract management, inspections, progress review, and resolving day-to-day issues. Dedicated project managers should be appointed for the entire project cycle. Given the limited resources of distribution utilities, third-party, quality-assurance consultants should be hired on a competitive basis to conduct field supervision and factory inspections.

Institutionalize the principles of load segregation. Feeder load segregation is not a one-time activity. Longer-term sustainability requires developing and institutionalizing the system to ensure that the principles of load segregation are followed across the organization (e.g., when new connections are released or feeder-failure events occur).

Ensure regulatory acceptance. From the project outset, keeping state regulators informed of all key decisions is critical to facilitating required regulatory investment approvals. Incorporating regulatory expectations into the project's documented objectives can enhance regulatory buy-in on project results and future regulatory engagement when, based on the project results, agricultural and rural consumption norms are revisited.

Use IT-based solutions. IT systems should be used to support automated data collection and analysis and M&E. Depending on the load segregation model that the state adopts, installations can be at the feeder, DT, or consumer level. IT-based solutions can help utilities overcome the dearth of available manpower for remote meter reading, manual errors in data recording, and lack of detailed consumption data for future analysis. Because these solutions represent a paradigm shift from business as usual, substantial change management is required to implement institutional and governance reforms to maximize the benefits of load segregation investments.

Monitoring and Evaluation

After project execution, the final phase of the cycle is monitoring and evaluation (M&E)—a dynamic process comprising regular feedback on post-implementation benefit estimates and results-sharing with key stakeholders and decision makers. The main steps of the M&E process are as follows:

20. The project management structure and allocation of responsibilities should be decided on during the project's conceptualization and planning phase.

- Appoint a creditable third party for quality-assurance M&E.
- Set up a knowledge hub on rural power supply.
- Disseminate results and share experience and lessons learned with stakeholders and utilities.

Appoint a creditable third party. The implementing utility or state government or regulator should appoint a creditable third party to evaluate both the financial and socioeconomic benefits of the rural load segregation scheme and document improvements against the baseline. Evaluating the socioeconomic benefits requires analyzing a selected sample from the primary survey of end-user consumers. The sample selection must be based on relevant statistical techniques and should include all consumer classes impacted by load segregation. The benefit evaluation should not be initiated until at least one year after project completion to ensure that significant post-execution data is included.

Set up a knowledge hub. A knowledge hub or center of excellence should be established within the CEA to undertake the design and implementation of the rural power supply system.

Disseminate results and share experience and lessons learned. Results of the project evaluation should be disseminated to all concerned stakeholders, including the utilities. The implementing utility's experience and lessons learned should be captured and used to improve the design and implementation of future feeder load segregation schemes.

Summary Remarks

In 2011, the findings of this study were shared with six states through consultations with relevant ministries and distribution utilities. In Gujarat and Rajasthan, the sample cases for this study, the findings were broadly endorsed (appendix). Utility officials in Gujarat expressed a desire to move ahead with a pilot on direct subsidy delivery and an agriculture power supply system based on 100 percent consumer metering for willing customers (i.e., potato growers). In Rajasthan, effective load management post segregation has meant restricting increased peak demand to about 67 percent against a 130 percent increase in connected load of agriculture consumers. Madhya Pradesh is about to start a rural feeder segregation program based on the Gujarat model. Uttar Pradesh has formulated a program to set up separate substations for rural areas and sub-district towns, and Bihar intends to provide dedicated rural feeders for agriculture supply only. The diverse results of these state consultations reinforce the general finding that drivers of rural power supply differ markedly across Indian states; thus, solutions for improving rural power supply must be customized to fit each state's requirements.

Appendix: Consultations Held in Gujarat, Rajasthan, and Madhya Pradesh

Gujarat: Minutes of Meeting with the Principal Secretary of Energy and Petrochemicals		
Meeting topic	Sharing findings of World Bank study on rural feeder load segregation	
Date/location	October 4, 2011/Gandhinagar	
Attendees	**Gujarat** D. J. Pandian, Principal Secretary, Secretary of Energy and Petrochemicals S. B. Raval, Managing Director, PGVCL C. L. Sharma, Chief Engineer, UGVCL N. Srivastava, Managing Director, UGVCL Suresh Shahdadpuri, Chief Nodal Officer (e-Urja and RAPDRP-A), UGVCL	**World Bank team** Ashish Khanna Kavita Saraswat Pricewaterhouse Coopers (PwC) Mohammad Saif
Agenda items	Sharing findings with and receiving feedback from the Gujarat power-sector team on the rural feeder load segregation study. Discussing state-specific issues in preparation for the proposed national guidance note on rural load segregation.	
Components	Discussion points	
Field visits	Prior to the meeting, the World Bank study team visited the UGVCL Energy Management Center, UGVCL Area Load Dispatch Center, Rupal village (to interact with rural consumers covered under the JGY), and the Randheja substation. The team noted that UGVCL has implemented automatic data acquisition at the feeder level and is conducting effective energy management and auditing. Load scheduling implemented through the Area Load Dispatch Center allows the utility to restrict its peak demand to about 3,000 MW against a connected load of 7,300 MW (figures quoted by the utility).	
Sharing of study findings	The World Bank team presented the study background, approach, and key findings. The audience agreed with the study findings specific to Gujarat. The UGVCL Managing Director noted that the agriculture subsidy, as included in the study, pertains only to unmetered agricultural consumption. It was suggested that the study report highlight the total subsidy against agricultural consumption. The requisite data was subsequently requested from the concerned official.	
State-specific queries and inputs for national guidance note	**Scheme data not utilized for agriculture approvals.** Gujarat still uses fixed consumption norms for unmetered consumers as part of regulatory submissions. It was agreed that the actual agricultural data should be shared with the regulator to finalize the annual unmetered consumption. **Marginal investments in remote meter reading to enable web-based disclosure of agricultural data.** While individual agricultural consumption might not be disclosed publicly, feeder/DT-level data can be publicly shared for transparency. The Principal Secretary suggested that, for all states that have successfully segregated rural load, the central government should provide financial support for installing RMR infrastructure on segregated feeders. **Moving from load segregation to individual metering to enable direct subsidy delivery.** Gujarat is ready to evaluate the direct subsidy model on a pilot basis; however, it was agreed that the pilot would require installing advanced metering infrastructure to extract the requisite data from end-user consumers. **Key JGY lessons to carry forward to other states interested in similar initiatives:** • A strong procurement system (including material, quality, and vendor management systems) must be in place before initiating such state-level schemes. • The key challenge is the demand for 24-hour supply by greenhouse consumers supplied through segregated agriculture feeders. • The Managing Directors' view was that the model to be followed eventually is 100 percent consumer metering supported by AMR, which can contribute to direct-subsidy delivery in rural areas by implementing time-of-day tariffs. A group of agricultural consumers is willing to pay the market price for reliable, good-quality power. These initiatives could be started with this group.	

Rajasthan: Minutes of Meeting with the Secretary of Energy		
Meeting topic	Sharing findings of World Bank study on rural feeder load segregation	
Date/location	October 12, 2011/Jaipur	
Attendees	**Rajasthan** Shailendra Agarwal, Chairman and Managing Director, RVPNL Y. K. Raizada, Technical Director, RVPNL Naresh Pal Gangwar, Secretary of Energy, Government of Rajasthan A. K. Gupta, Technical Director, JVVNL Finance Director, JVVNL Superintendent Engineer, Jaipur City, JVVNL T. S. Sharma, Superintendent Engineer/MIS, JVVNL	**World Bank team** Ashish Khanna Kavita Saraswat Pricewaterhouse Coopers (PwC) Mohammad Saif
Agenda items	Sharing findings with and receiving feedback from the Rajasthan power-sector team on the rural feeder load segregation study. Discussing state-specific issues in preparation for the proposed national guidance note on rural load segregation.	
Components	Discussion points	
Field visits	Before the meeting, the World Bank study team visited the Bassi subdivision selected for the load segregation study. The team was informed that agriculture consumers are connected through HVDS, and meters are provided on all transformers; thus, consumers are metered on a 100 percent basis. However, some meters are defective. No IT-based solution has been implemented to read and process the data.	
Sharing of study findings	The World Bank team presented the study background, approach, and key findings. The audience raised the following key points: • Increased agriculture connections post completion of the FRP were due primarily to the release of all pending connections for the past 10–15 years, increased supply hours to agriculture consumers, and the rise in connected load per consumer due to groundwater depletion. The team indicated that the study report would be updated to reflect this information. • Rajasthan was regulating the supplied agriculture connections even before the FRP was initiated; thus, the FRP might not result in the flattening of the demand load curve as in Gujarat. It was agreed that the requisite data substantiating this statement would be shared with the study team for further analysis and validation. • Because subdivisions in Rajasthan differ significantly, the study report should include a caveat highlighting that the detailed study was limited to a sample subdivision; this caveat was subsequently highlighted in the report.	
State-specific queries and inputs for national guidance note	**Primary objectives of load segregation.** The primary objective was improving the quality and hours of supply for rural consumers. **Scheme data not utilized for agriculture approvals.** Unmetered agriculture consumers are billed using standard consumption norms prescribed by the regulator. While unmetered consumers have individual meters on DTs, they are not read regularly. It was agreed that actual consumption data can be used for approvals from the regulator. **Marginal investments in remote meter reading to enable web-based disclosure of agricultural data.** Most existing DT metering of agriculture lacks a communication facility. To date, the data has not been compiled owing to the large capital investments required and equipment security concerns. **Key FRP lessons to carry forward to other states interested in similar initiatives:** • The new FRP scheme proposed will integrate the installation of energy-efficient pump sets as a demand-side mechanism (DSM) measure. • Agri-products should be linked to the subsidy. • Smaller transformers (10 kVA) should be used in HVDS.	

Madhya Pradesh: Minutes of Meeting with the Distribution Utilities

Meeting topic	Sharing findings of World Bank study on rural feeder load segregation	
Date	October 19, 2011	
Attendees	**Madhya Pradesh** Nitesh Vyas, Managing Director, Madhya Pradesh MKVVCL Feeder separation project team members from the three Madhya Pradesh distribution utilities Representatives of the REC	**World Bank team** Ashish Khanna Pricewaterhouse Coopers (PwC) Mohammad Saif
Agenda items	Sharing the study findings from Gujarat and Rajasthan on rural feeder load segregation. Discussing the proposed institutional framework for load segregation and its applicability to the Madhya Pradesh distribution utilities.	
Components	Discussion points	
Sharing of study findings	The World Bank team presented the study background, approach, and key findings in the context of their relevance to the Madhya Pradesh rural load segregation scheme. The Madhya Pradesh team shared the following information. Madhya Pradesh distribution utilities have a total of 75 segregation schemes, averaging about US$9.4–11.3 million (Rs. 50–60 crores) per scheme. A third-party project management consultant has been hired to manage the planning, design, execution, and monitoring of the scheme. Nine months have passed since the contract for execution was awarded; no pilots were undertaken. Execution of the scheme will be outsourced using turnkey contracts. The distribution utilities have decided to adopt the Gujarat model of physical feeder segregation and aim to restate their distribution losses post segregation. The East distribution utility has prepared a separate scheme for installing feeder/DT-level automated metering infrastructure on the segregated feeders. The decision to connect agriculture or non-agriculture load to the new feeder created as a result of physical segregation will depend on the respective load proportions on a given feeder.	
Institutional framework for load segregation	A general framework for undertaking load segregation was prepared using the study findings presented. The rural load segregation scheme of Madhya Pradesh was mapped onto the framework. The key highlights were as follows: • **Strategic objective.** In Madhya Pradesh, the primary objective of feeder segregation is continuous supply to non-agriculture rural consumers. The approach is physical segregation without HVDS, except where agriculture connections have high connected load. Feeder segregation is planned for selected state districts where feeders have been selected, based on existing loss levels. • **Conceptualization** – Technical and operational evaluation. Key positives for the proposed approach to load segregation are low metering of agriculture connections in the state, large scope for peak load management, and ability to control supply hours on agriculture feeders. However, high financial losses of state utilities and existing inadequate supply are deterrents to the proposed scheme. – Socioeconomic status in rural areas. The physical separation may be comparatively costly owing to the state's large geographical spread. However, the scheme would require limited communication with farmers compared to other load segregation models. – Execution and evaluation phases. The three project teams of the distribution utilities were updated on basic project requirements to ensure a robust and successful execution of the scheme and its subsequent evaluation. These include (i) preparation of a robust baseline and subsequent financial and technical targets; (ii) procurement strategy that optimizes existing state practices through a cell with technical and project management expertise; (iii) tier-based project management for robust monitoring; (iv) continuous regulatory engagement from the outset of the evaluation phase; (v) use of advanced metering infrastructure to support data collection, monitoring, and evaluation of the scheme; (vi) third-party inspections during and after project execution, and (vii) engaging a creditable third party to evaluate both the financial and social costs and benefits of the scheme vis-à-vis the documented baselines.	

Madhya Pradesh: Minutes of Meeting with Water Resource Department		
Meeting topic	Sharing findings of World Bank study on rural feeder load segregation with the Principal Secretary of the Water Resource Department, Madhya Pradesh	
Date	October 19, 2011	
Attendees	**Madhya Pradesh** R. S. Julaniya, Principal Secretary, Water Resource Department	**World Bank team** Ashish Khanna Pricewaterhouse Coopers (PwC) Mohammad Saif
Agenda items	Sharing the study findings from Gujarat and Rajasthan on rural feeder load segregation. Discussing the impact of Madhya Pradesh's upcoming rural load segregation scheme on the state's groundwater reserves.	
Components	Discussion points	
Sharing of study findings	The Principal Secretary was updated on the study undertaken in Gujarat and Rajasthan. Details of the ongoing load segregation scheme by the distribution utilities in Madhya Pradesh were also shared.	
Impact of load segregation on groundwater reserves	The impact of rural load segregation on the state's groundwater levels was discussed at length. The views shared by the Principal Secretary were as follows: • Every three years, the state water department conducts a study of the depleted blocks. According to the results of these studies, there is a 5 percent marginal increase in the depleted blocks. The groundwater situation appears alarming due to variations in the block classification criteria adopted in various studies; thus, feeder segregation is not expected to have a large impact on the state's groundwater levels. • Feeder segregation must be primarily an energy-sector scheme; inter-linkages with other sectors would make it difficult to coordinate across departments. • The agriculture business does not receive requisite returns, which explains the need for subsidy to farmers. The agriculture subsidy can be removed if the agriculture sector can be assured of needed financial returns.	

5

The Way Forward

This study has demonstrated that there is no one-size-fits-all solution to improving rural power supply. Project proposals should be evaluated as part of each state's broad strategic program for improving rural power supply. Given the enormous amounts of planned or already allocated investments by various states in India, there is an urgent need to establish centralized rules of engagement outlining the principles that should underpin the design of any initiative to improve the sustainability of rural power supply while maintaining techno-economic viability.

The final results of this study were presented to India's Ministry of Power in April 2012. Based on these consultations, several key recommendations were made. First, it was decided that a knowledge hub or center of excellence should be established within the Central Electricity Authority (CEA) to undertake the design and implementation of the rural power supply system. It was also advised that one or two states far along in implementing their feeder load segregation schemes create integrated data centers to collect and analyze data for such strategic purposes as ensuring transparency in determining subsidies for distribution utilities and improving operational efficiency. Furthermore, it was decided that one or two states on the threshold of undertaking rural load segregation should be selected to work with the CEA on the conceptualization and design of improved rural power supply.

At the central level, setting rules of engagement and principles for ensuring improved rural power supply while maintaining techno-economic viability can be achieved using a common strategic framework for designing the most optimal system. If feeder load segregation emerges as the best solution, it should be amenable to the direct delivery of subsidies to farmers. Improved measurement and reliability of agricultural consumption data are essential starting points that could lead to a win-win situation for all stakeholders. Automated meter reading (AMR) and similar initiatives based on information technology should be an integral part of rural power system design.

The recommended knowledge hub set up within the CEA should be responsible for developing standard documentation templates for the Detailed Project Report (DPR), as well as project management and operational manuals, technical specifications, and standard bidding documents. In addition, it should develop processes for project implementation, data management, and integrated operations to ensure the sustainability of the rural power supply system. The knowledge hub can assist states that desire to follow the strategic framework with project design and implementation, including the use of AMR. Finally, the experiences and outcomes of the demonstration projects should be widely disseminated by the knowledge hub so that lessons in success can be replicated across the country.

ANNEX

State Profiles

This annex provides summary profiles of the four Indian states included in the rural feeder load segregation study: Andhra Pradesh, Gujarat, Rajasthan, and Haryana. Each summary highlights key information, including dates of power sector reform, technical and financial trends of the distribution utilities and consumer mix, state climate and crop characteristics, and elements of the segregation scheme.

Andhra Pradesh

Andhra Pradesh is India's third largest state, with an area of 276,754 km^2.It accounts for 8.4 percent of the country's territory and has its longest coastline (972 km). The state is endowed with a variety of physiographic features, ranging from high hills to undulating plains and a coastal deltaic environment.[21] Andhra Pradesh ranks fifth in terms of population, at about 84.7 million.[22] In 2010, state GDP was US$77.6 billion (Rs. 4.1 trillion), accounting for 7.63 percent of the country's GDP. In FY2008–09, agriculture and agriculture-related services contributed 26.34 percent of state GDP, compared to 10.73 percent for manufacturing industries and 47.81 percent for the services sector.[23] The state's literacy rate is 67.66 percent, about 6 percent lower than the national average.

Power Sector Reform

The Andhra Pradesh State Electricity Board (APSEB), formed in 1959, was responsible for all three power-sector functions: generation, transmission, and distribution. The Andhra Pradesh Electricity Reform Act, enacted in 1998, provided for the constitution of the Electricity Regulatory Commission and restructuring of the power industry. In early 1999, the APSEB was unbundled into APGENCO and APTRANSCO. The following year, APTRANSCO was further unbundled so that its management was limited to transmission, while four utility companies were formed to manage distribution in the state's central, eastern, northern, and southern zones, respectively.[24]

Technical and Financial Trends

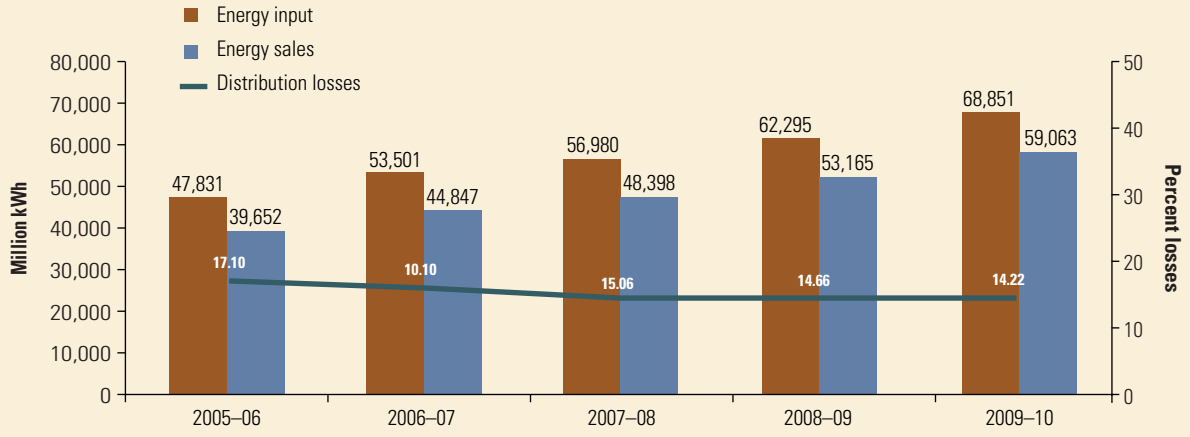
In recent years, Andhra Pradesh has witnessed a continuing decline in distribution losses (figure A.1). At the same time, the subsidies booked by the distribution utilities have been less than those received from the state government, causing financial losses to increase (figure A.2).[25]

Consumer Profile

The Andhra Pradesh distribution utilities have 14 percent representation of agriculture consumers in the consumer base, and 32 percent share of agricultural consumption, the same percentage as industrial sales (figure A.3). Consumption against unmetered agriculture use is higher than against metered agriculture use.[26]

21. Government of Andhra Pradesh official portal.
22. 2011 census.
23. Details are available at http://www.indiastat.com.
24. As reported by the People's Monitoring Group on Electricity Regulation (PMGR).
25. Power Finance Corporation (PFC) performance report.
26. Projected values for FY2009–10, according to the Andhra Pradesh Electricity Regulatory Commission (AERC) tariff order for the state distribution utilities.

FIGURE A.1 ENERGY INPUT AND SALES TREND, ANDHRA PRADESH



Source: PwC.

Agriculture Profile: Climate and Crops

Andhra Pradesh is characterized by a generally hot and humid climate. A reasonably long coastal belt accounts for the state's relatively mild winters. Agricultural production depends heavily on seasonal rainfall distribution. The two most important sources of rainfall are the southwest and northwest monsoon winds, occurring in June–September and October–December, respectively. The net area cultivated comprises 39.4 percent of the total land area (2007–08 figure).

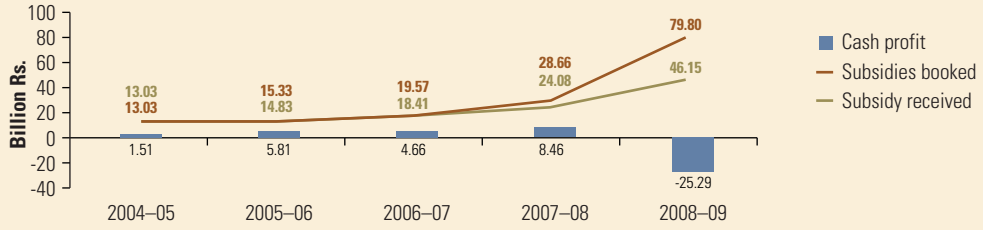
Rice is the state's major staple crop. Various other important crops include jowar, bajra, maize, small millet, pulses, tobacco, cotton, and sugarcane. Cropping intensity—the ratio of gross area sown to net area sown—is 1.26 (FY2007–08 figure). In FY2005–06, total irrigated area represented 27.8 percent of total cultivated area. Irrigation intensity—the ratio of gross irrigated area to net irrigated area—is 1.35 (FY2007–08 figure).[27]

Rural Load Segregation

Initially, a virtual-segregation scheme was applied for all mixed rural feeders, and was completed in 2005. However, this approach limited the three-phase supply available to non-agriculture rural consumers. In response, physical segregation has been planned and pilots are under way. The key objectives of physical load segregation are to (i) make three-phase supply available to rural consumers 24 hours a day in order to boost small rural industries and thus improve socioeconomic benefits and (ii) extend the daily 7–9 hours of three-phase supply available for pump sets.

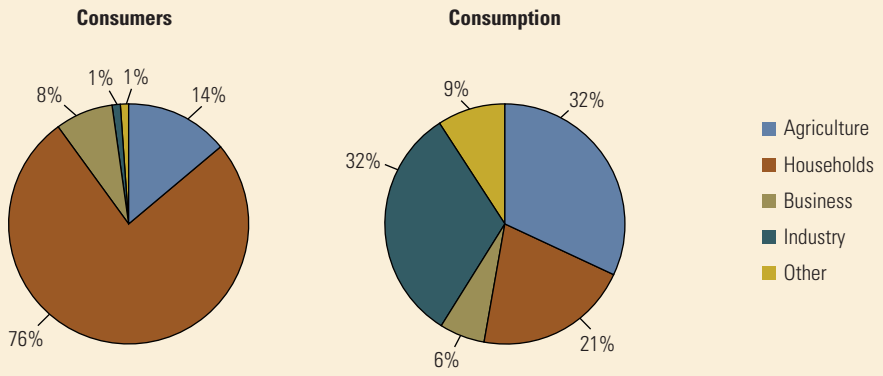
27. Details are available at http://agri.ap.nic.in/rainfallsenario.htm.

FIGURE A.2 RECENT TREND IN STATE SUBSIDIES AND FINANCIAL LOSSES, ANDHRA PRADESH



Source: PwC.

FIGURE A.3 CONSUMER AND CONSUMPTION MIX OF DISTRIBUTION UTILITIES, ANDHRA PRADESH



Source: PwC.

Currently, there are about 13,731 feeders across the state's four distribution companies; of these, 8,878 are mixed rural feeders. The draft Detailed Project Report (DPR) on segregating all agriculture feeders, prepared in August 2010, estimates the total cost of segregating mixed rural feeders at about US$568.7 million (Rs. 30.14 billion).

Gujarat

Gujarat state, located in northwest India, is the country's seventh largest state, with a total land area of 196,077 km^2. The state is bordered by Rajasthan to the northeast, Madhya Pradesh to the east, and Maharashtra and the Union territories of Diu, Daman, Dadra, and Nagar Haveli to the south. The Arabian Sea borders the state to both the west and southwest.[28] Gujarat's population, at 60.38 million, accounts for about 5 percent of the country's total population.[29] In FY2010, the state GDP was US$71.7 billion (Rs. 3.8 trillion),[30] accounting for 6.89 percent of India's total GDP. Agriculture and agriculture-related services contribute more than 14 percent of state GDP, compared to about 31 percent for manufacturing industries and 41.12 percent for the services sector (FY2008–09 figure). The state's literacy rate is 79.31 percent, 5.27 percent higher than the national average.

Power Sector Reform

The Gujarat Electricity Industry Reorganization and Regulation Act, passed in 2003, restructured the electricity industry with the goal of improving the efficiency of management and delivery of consumer services. Under the Act's provisions, the government framed the Gujarat Electricity Industry Reorganization and Comprehensive Transfer Scheme of 2003, whereby the Gujarat Electricity Board was reorganized into seven successor companies with separate responsibilities for electricity trading, generation, transmission, and distribution (effective April 1, 2005).[31]

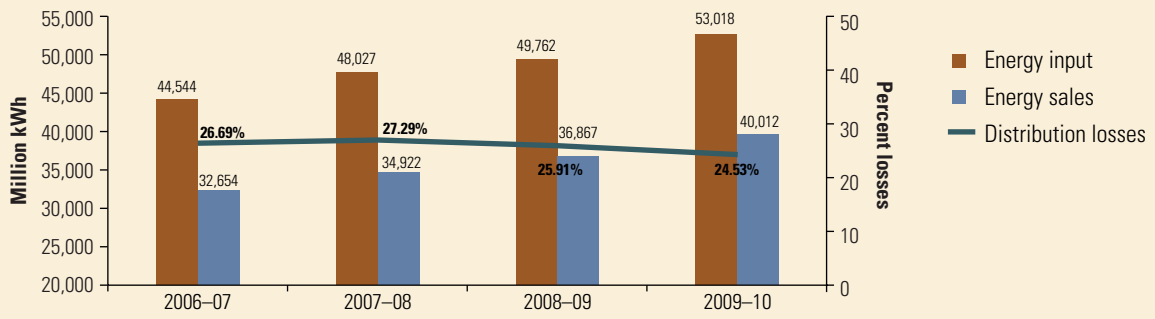
Technical and Financial Trends

The FY 2007–08 socioeconomic review of Gujarat's Directorate of Economics and Statistics estimated the state's per capita electricity consumption at 1,354 kWh, which is much higher than the national average. In recent years, energy input and sales have increased,[32] while distribution losses have declined somewhat (figure A.4).

Gujarat is one of the few Indian states where the distribution utilities have a profitable balance sheet. For most years, the subsidies booked by the utilities, based on the government's prior consent, and the subsidies received are equal (figure A.5).

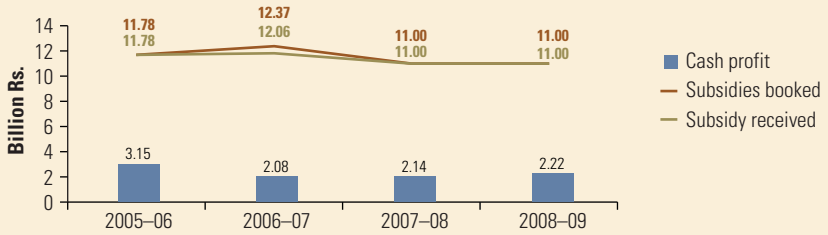
28. Government of Gujarat official portal (http://www.gujaratindia.com).
29. 2001 census.
30. Official Gujarat state portal, Department of Industry.
31. Official website of Gujarat Urja Vikas Nigam Ltd (GUVNL).
32. Aggregate revenue requirement (ARR) tariff order for the respective distribution utilities.

FIGURE A.4 ENERGY INPUT AND SALES TREND, GUJARAT



Source: PwC.

FIGURE A.5 RECENT TREND IN STATE SUBSIDIES AND DISTRIBUTION PROFITS, GUJARAT



Source: Power Finance Corporation (PFC) performance report.

Consumer Profile

In FY2008–09, Gujarat's distribution utilities had a total consumer base of approximately 10 million, of which agriculture consumers accounted for 8 percent. Over the same period, sales to agriculture consumers totaled 32 percent (figure A.6).

Agriculture Profile: Climate and Crops

Well over half of Gujarat's total land area can be characterized as arid and semi-arid (i.e., 24.94 percent in the arid zone and 33.66 percent in the semi-arid zone). Average annual rainfall varies widely throughout the state, ranging from just 300 mm in the western part of Kutch to 2,100 mm in the southern part of Valsad district and the Dangs. The monsoons arrive in mid-June and recede by late-September. About 95 percent of total annual rainfall is received during these months, with the maximum number of rainy days occurring in July and August.

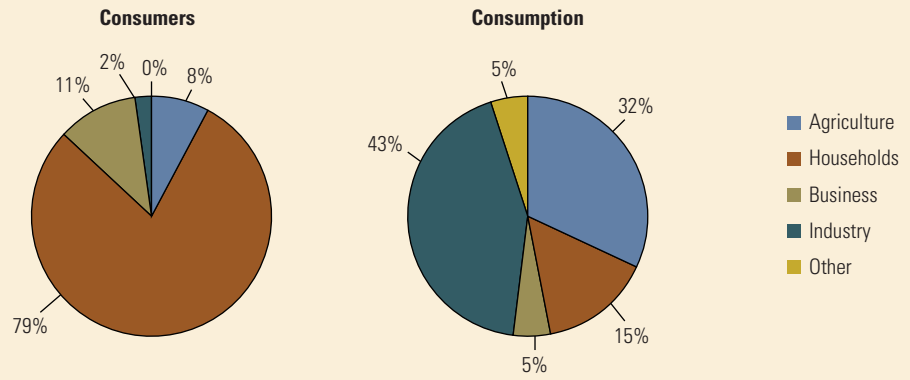
The state features a wide diversity of major crops, including wheat, bajra, rice, maize, groundnut, mustard, sesame, pigeon pea, green gram, sugarcane, and cotton. Gujarat is India's largest producer of castor, tobacco, and isabgul (psyllium) and its second largest producer of sesame seed, cotton, and groundnut. Most crops sown in winter and harvested in spring (rabi) and all summer crops require irrigation; however, most crops sown during the monsoon (kharif) are rainfed. Double-crop, irrigated annual plantings have an estimated cropping intensity of 103–120 percent, averaging about 113 percent. The agriculture sector consumes a large percentage of surface water and groundwater for irrigation. Even so, gross irrigated area accounts for only 31.8 percent of the gross area sown.

Rural Load Segregation

In Gujarat, rural load segregation was introduced as part of the Jyoti Gram Yojna (JGY), with the goal of supplying continuous quality rural power supply. Introduced in 2003–04, JGY covered more than 18,000 electrified villages.[33] All mixed rural feeders were physically segregated

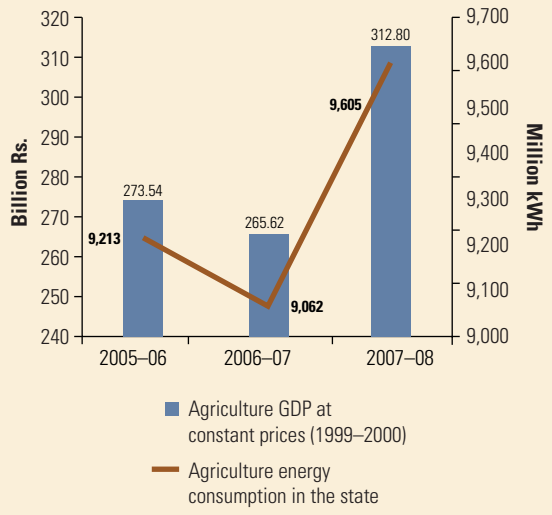
33. Energy and Petro Chemicals Department, Government of Gujarat.

FIGURE A.6 CONSUMER AND CONSUMPTION MIX OF DISTRIBUTION UTILITIES, GUJARAT



Source: Gujarat Electricity Regulatory Commission order on annual performance review for FY2009–10 (http://agri.gujarat.gov.in/).

FIGURE A.7 AGRICULTURAL ENERGY CONSUMPTION AND GDP POST JGY



Source: PwC.

into JGY and agriculture-dominated feeders. JGY feeders provide rural households, commercial, and industrial users a continuous power supply, while ag-dominated feeders supply fixed duration power for agriculture use.

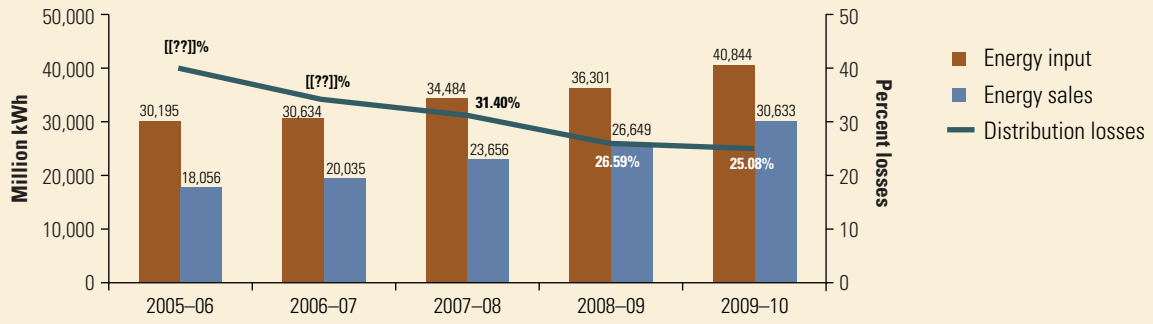
Before JGY, virtual segregation was prevalent. During project execution, the concept of special design transformers was introduced, whereby farmers in remote areas would receive a continuous single-phase supply through ag-dominated feeders. Implemented from FY2002–03 to 2005–06, the scheme resulted in the creation of 1,904 JGY feeders, at a total cost of about US$243.4 million (Rs. 12.9 billion),[34] largely funded through a state grant. Since the JGY program ended, both agricultural energy consumption and agriculture GDP have generally trended upward following a slight dip in FY2005–06 to 2006–07 (figure A.7).

Rajasthan

Located in northwest India, Rajasthan is India's largest state in terms of land area, with a total of 342,269 km^2. The state is bordered on the west and northwest by Pakistan, on the north and northeast by Punjab, Haryana, and Uttar Pradesh, on the east and southeast by Uttar Pradesh and Madhya Pradesh, and on the southwest by Gujarat.[35] Its population, about 68.62 million,[36] accounts for 5.67 percent of the country total. For FY2010–11, state GDP was projected at US$57.2 billion (Rs. 3.03 trillion), with a 9.69 percent growth rate. The agriculture sector contributed 26 percent of state GDP, compared to 27 percent for manufacturing industries and 47 percent for the services sector.[37] In 2001, the state ranked ninth in terms of the human development index. Its literacy rate is 67.06 percent, about 7 percent below the national average.[38]

34. According to Gujarat's JGY cell.
35. Official website of Government of Rajasthan.
36. 2011 census.
37. 2001 census, website of Directorate of Economics and Statistics, Government of Rajasthan.
38. Official website of Department of Industries, Government of Rajasthan.

FIGURE A.8 ENERGY INPUT AND SALES TREND, RAJASTHAN



Source: PwC.

Power Sector Reform

A year after passage of the 1999 Power Sector Reform Act, the Rajasthan State Electricity Board was unbundled into five successor entities with separate functions for power generation, transmission, and distribution. As a result, three independent distribution companies were formed: Jaipur, Ajmer, and Jodhpur Vidyut Vitran Nigam Ltd.

Technical and Financial Trends

Since 2005, distribution losses in Rajasthan have steadily declined (figure A.8)[39] But the subsidy requirements projected by the distribution utilities have risen, while the subsidies received have remained flat (figure A.9).

39. Audited account statements of Rajasthan's distribution utilities.

Consumer Profile

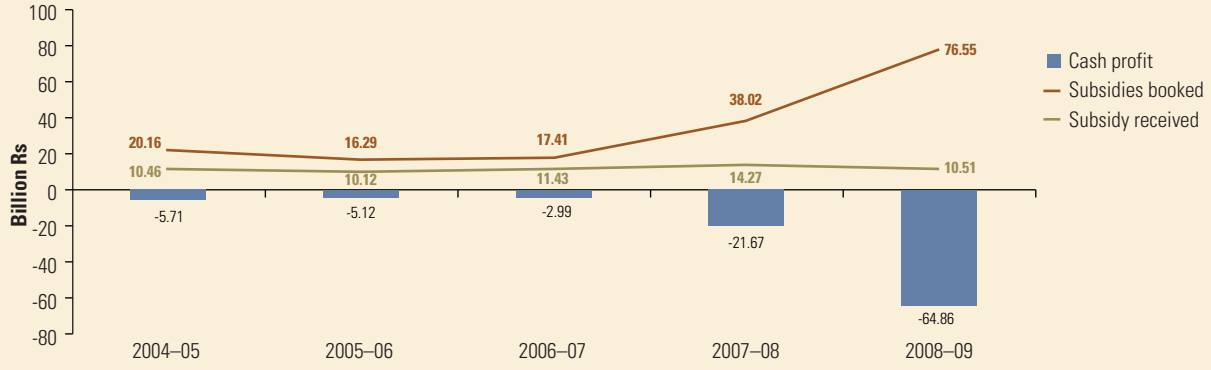
Rajasthan's distribution utilities have a total consumer base of approximately 5.3 million, of which agriculture consumers account for 12 percent (FY2009–10 figures). For FY2011–21, the utilities projected agriculture consumer sales at 39 percent (figure A.10).[40]

Agriculture Profile: Climate and Crops

Rajasthan's climate is characterized, in large part, by arid and semi-arid conditions, with erratic and uneven rainfall distribution. The state depends heavily on rainfed agriculture. Of the 21.6 million ha in cultivated area, assured irrigation covers only 6.4 million ha. Even so, Rajasthan is

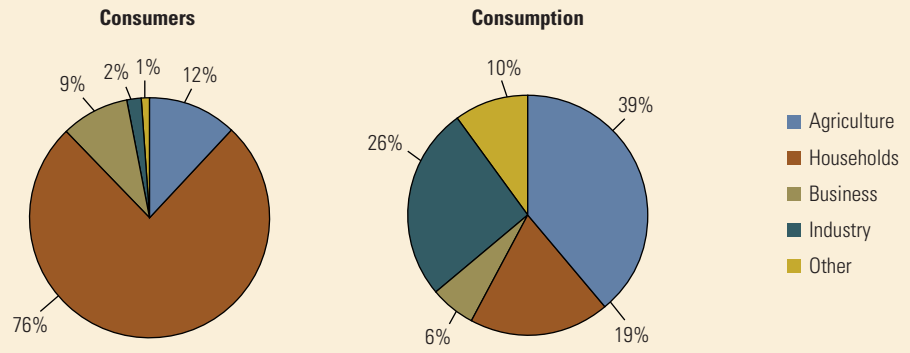
40. Consumer business plan (FY2010–11 to 2014–15) and consumption-ARR and retail tariff petitions (FY2011–12) of Rajasthan distribution utilities.

FIGURE A.9 RECENT TREND IN STATE SUBSIDIES AND FINANCIAL LOSSES, RAJASTHAN



Source: PwC.

FIGURE A.10 CONSUMER AND CONSUMPTION MIX OF DISTRIBUTION UTILITIES, RAJASTHAN



Source: PwC.

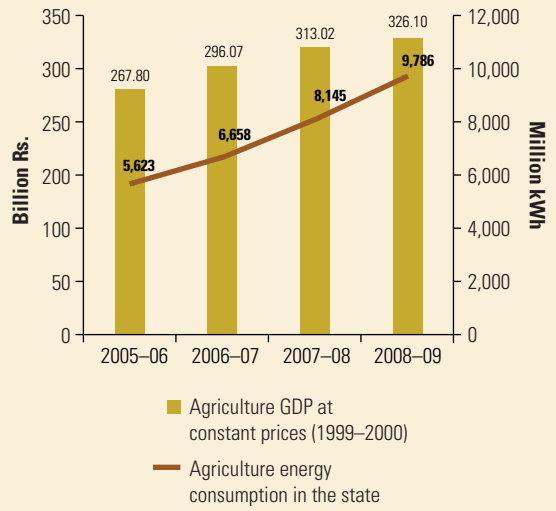
a leading producer of coarse cereal. Wheat and barley are cultivated over large areas, as are pulses, sugarcane, and oilseeds. Cotton and tobacco are major cash crops. The state is among India's largest producers of edible oils and is its second largest producer of oilseeds.[41]

Rural Load Segregation

Load segregation in Rajasthan was initiated in 2005 as part of the Feeder Renovation Program (FRP). The scheme's main objective was to reduce distribution losses on mixed rural feeders and provide increased supply to non-agriculture rural households. The FRP was integrated with other system strengthening elements, including HVDS on agricultural feeders, DT metering, and replacement of LT cables with ABC.

Rajasthan adopted virtual segregation, whereby single-phase DTs were installed on existing rural feeders for household and non-household loads. A roster switch was used to balance three-phase, agricultural supply hours with single-phase hours when households received an unrestricted supply. The FRP covered a total of 8,126 feeders, with a total planned outlay of approximately US$846.2 million (Rs. 44.85 billion). Since 2005–06, agricultural energy consumption and agriculture GDP have consistently trended upward (figure A.11).

FIGURE A.11 AGRICULTURAL ENERGY CONSUMPTION AND GDP AFTER FRP INITIATION



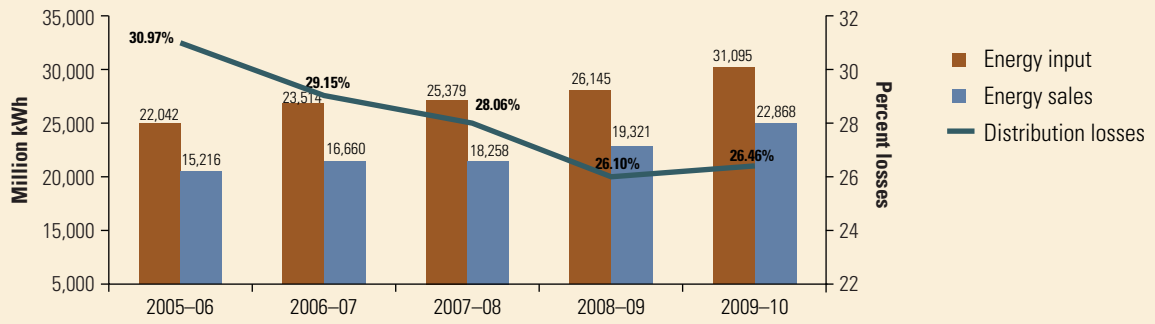
Source: PwC.

Haryana

Haryana, one of India's most prosperous states, is situated in the northwestern part of the country. It is bordered by Uttar Pradesh to the east, Punjab to the west, Himachal Pradesh to the north, and Rajasthan to the south. The national capital territory of Delhi juts into the state. Its total geographic area is 44,212 km^2. Haryana is home to more than 25.35 million people, with a population density of 573.4 persons per km^2. State GDP is estimated at about US$40.8 billion (Rs. 2.2 trillion) (FY2009–10 figure). Agriculture and agriculture-related services account for 16.1 percent of state GDP, compared to 30.5 percent for manufacturing industries and 53.4 percent for the services sector. Per capita income is

41. Details are available at http://www.rajasthankrishi.gov.in/.

FIGURE A.12 ENERGY INPUT AND SALES TREND, HARYANA



Source: PwC.

estimated at Rs 78,781 (FY2009–10 figure).[42] The state's literacy rate is 71.40 percent, about 3 percent below the national average.

Power Sector Reform

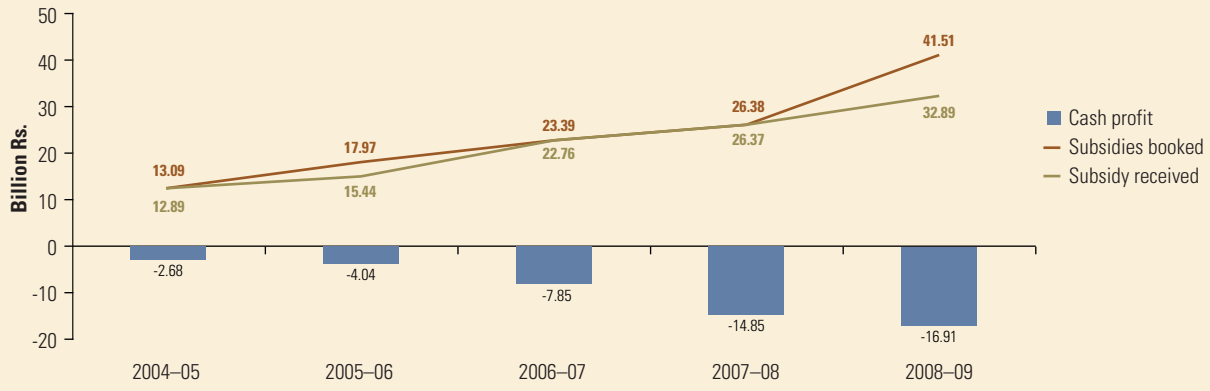
Subsequent to the Haryana Reform Act of 1998, the state government unbundled the Haryana State Electricity Board into two independent companies: Haryana Power Generation Corporation Ltd (HPGCL) and Haryana Vidyut Prasaran Nigam Ltd (HVPNL). HPGL was put in charge of electricity generation, while HVPNL was responsible for transmission, distribution, and retail supply. The following year, two distribution companies—Uttar Haryana Bijli Vitran Nigam Ltd (UHBVNL) and Dakshin Haryana Bijli Vitran Nigam Ltd (DHBVNL)—were separated from HVPNL to focus exclusively on distribution and retail supply in their respective geographic areas.

Technical and Financial Trends

In recent years, energy input and sales in Haryana have trended upward, as distribution losses have generally declined (figure A.12). However, the subsidies required by the distribution utilities have exceeded the amounts received, causing financial losses to increase (figure A.13).

42. http://www.esaharyana.gov.in.

FIGURE A.13 RECENT TREND IN STATE SUBSIDY AND FINANCIAL LOSSES, HARYANA



Source: PwC.

Consumer Profile

Distribution utilities in Haryana have a total consumer base of approximately 4.5 million. Of this number, agriculture consumers account for just 11 percent, yet represent 39 percent of total sales (figure A.14).[43]

Agriculture Profile: Climate and Crops

Haryana's climate varies from arid to semi-arid. Contrasting seasons feature hot summers, with temperatures rising up to 50°C in May and June, and cold winters, with temperatures falling to as low as 1°C in December and January. Average annual rainfall is 455 mm; about 70 percent occurs between July and September and the remainder in December–February. Rainfall distribution is uneven, with the Shivalik Hills region receiving the largest amounts and Aravali Hills the least.

Eight-six percent of Haryana's total land area of 4.4 million ha is arable (i.e., 3.8 million ha); of this amount, 96 percent is under cultivation. The state has a net cropped area of 3.62 million ha, with a cropping intensity of 177 percent. The northwest climate zone is suitable for growing rice, wheat, vegetables, and temperate fruits, while the southwest is suitable for high-quality produce, tropical fruits, exotic vegetables, and herbal and medicinal plants. Crop production can be broadly group into winter season (rabi) (e.g., chili, bajra, jawar, pulses, and vegetables) and rainy season (kharif) (e.g., sugarcane, groundnut, maize, and paddy). Irrigation, a major source of water for cultivation, depends on the various canals operating throughout the state (e.g., Western Yamuna, Gurgaon, Jui, Jawaharlal Lal Nehru, and Bhakra).[44]

Rural Load Segregation

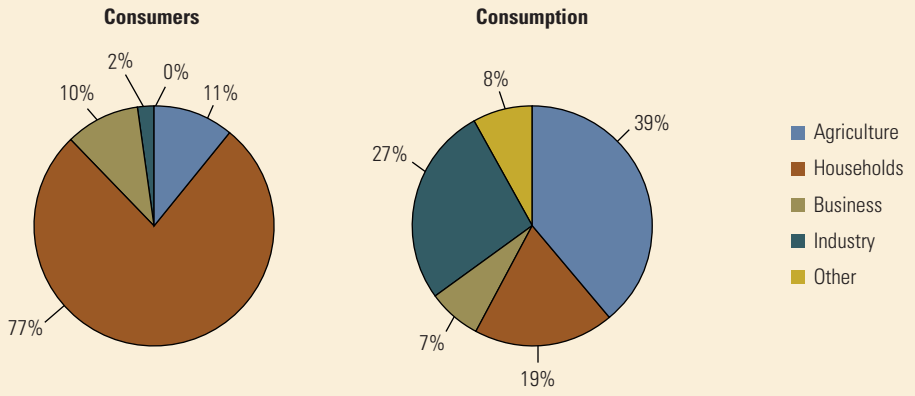
Haryana's scheme for rural load segregation, initiated in FY2005–06, aimed to regulate supply to rural consumers by providing rural households urban patterns of power supply, improving voltage, stabilizing the distribution system, and reducing system losses. The scheme separated rural domestic load from agriculture load by erecting dedicated 11-kV feeders. Under the scheme, 1,226 new feeders were erected with a total length of 17,308 km. All feeders were equipped with bulk meters.

Project implementation relied mainly on turnkey contracts awarded through the distribution utilities' planning and design units. In FY2006–07, multiple agencies were awarded contracts with planned completion dates within two years of the project starting date. Segregation work was delayed, but was completed in mid-2010 when subjected to regular monitoring by the state government.

43. Based on ARR petitions of DHBVNL and UHBVNL for FY2011–12.

44. More details are available at http://agriharyana.nic.in/.

FIGURE A.14 CONSUMER AND CONSUMPTION MIX OF DISTRIBUTION UTILITIES, HARYANA



Source: PwC.

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