



# TECHNICAL NOTE

## ADVANCING POWER SECTORS' SELF-RELIANCE THROUGH ELECTRICITY SYSTEM LOSS REDUCTION

### WHY DO WE CARE ABOUT LOSSES?

**What are electricity system losses and why do we, as development practitioners, care about them?**

***Total transmission and distribution losses (T&D losses) are the canaries in the coal mines** – they are the primary indicator by which you can quickly judge the financial and operational health of an electricity utility. In brief, T&D losses represent the amount of electricity produced and injected into the grid but not paid for by users due to technical inefficiencies and to theft, meter tampering, and billing and accounting errors. (See Box 1 for detailed definition). A well performing utility in a developing country may have a total loss level of 10% or below. By comparison, losses in the U.S. average about 5%. In the U.S., losses consist primarily of technical losses whereas in developing countries with high losses, they mainly consist of non-technical losses. Higher loss levels usually indicate poor management, corruption, and/or lack of resources and expertise in knowing how to address them, particularly where there are high concentrations of informal low-income settlements in the utility's service area that require creative, non-traditional solutions for loss reduction. A utility with high losses is unable to collect the revenues necessary to cover their operating costs and is “decapitalizing” or unable to maintain their system assets, resulting in outages and voltage fluctuations for existing customers and inability to expand to new customers.*

#### **Box 1: T&D Losses Defined**

T&D losses are comprised of technical and non-technical losses:

Technical losses occur naturally and consist mainly of power dissipation in electricity system components such as transmission and distribution lines, transformers, and measurement systems. To minimize technical losses, the system must be well designed, constructed, and maintained.

Non-technical (or commercial) losses are caused by actions external to the power system and consist primarily of electricity theft, meter-tampering, collusion with utility staff, and errors in accounting and record-keeping.

The problem of poorly performing utilities is immense in Sub-Saharan Africa (SSA). In 2016, the World Bank found that only two countries in SSA (Uganda and the Seychelles) have financially viable utilities. That is, these utilities can cover existing operating costs and capital costs to replace existing assets as required (but not future assets). All other SSA utilities depend on subsidies to cover operating costs and/or maintain existing asset bases. To upgrade, modernize or expand services, SSA utilities frequently rely on the donor community for capital infusions. The financial burden of subsidies on SSA Government coffers is on average 1.04% of GDP but can be as high as 6% in some countries. Economic costs are even higher when the impacts on industry and commerce of poor power supply, which is typical of a financially troubled utility, and of low electrification rates are considered. Furthermore, the poor financial performance of the utility hinders it from attracting private investment for new generation with developers, faced with a bankrupt off taker, often requiring guarantees from the Government and/or multi-lateral development institutions.

**Box 2: Illegal hookups in Majesty Gardens, Kingston Jamaica, with personal items identifying individual household's lines.**



**Losses are one of the four primary factors that determine a utility's financial performance.**

The others include underpricing (typically a result of political interference), under-collection of bills, and over-staffing. As noted in the 2016 World Bank report, "Combined network and collection losses on average represent a larger hidden cost and are less politically sensitive to address than underpricing, so could be a smart area for policy focus..." If you suspect that losses are a significant problem for your utility (perhaps you have seen the "spaghetti" wires depicted in Box 2), you can look up T&D losses for countries in [this World Bank database](#). Note that for many developing countries, this data may just be estimates as many utilities do not have the capacity, including metering infrastructure, methodologies and processes in place, to accurately measure T&D losses. Even if not completely accurate, data can be used to benchmark utilities and compare performance across utilities in the same region or of those serving a similar customer base. T&D data from a selection of countries is presented in Box 3.

**Box 3: Total T&D Losses (2014) for Selected Countries**

Country	T&D Losses (%)
Colombia	11
Ghana	23
Ethiopia	18
Iraq	51
Jordan	11
Nepal	32

Source: World Bank DataBank  
<https://data.worldbank.org/indicator/EG.ELC.LOSS.Z>

## HOW CAN LOSSES BE ADDRESSED?

Needless to say, addressing losses is of high importance to utilities and is often a key component of a larger utility reform or transformation strategy. Strong utility leadership and commitment to addressing losses is fundamental to motivating utility staff, attracting and deploying necessary resources and expertise, and combating any internal corruption contributing to losses. Without the highest levels of utility management (rather than, for example, a few technical staff) strongly pushing forward strategies and initiatives for reducing losses, achievements in loss reduction will generally be short-lived. Donor programs have sometimes invested heavily in infrastructure upgrades, including new metering, ICT solutions, and smart grids but reductions in losses have not been sustained where utilities have not developed and implemented an associated vision of improved utility management and corporate governance.

Once leadership has prioritized loss reduction, donors can assist the utility with designing and implementing one or more of the following programmatic phases for reducing losses:

### **(1) Collecting accurate customer, billing and network information:**

Conducting loss analytics requires the utility to have databases populated with complete and updated information on customers and their billing and network assets (e.g. meter, pole, transformer, etc.) and for these databases (often called the Customer Management System (CMS) and Network Information System (NIS)) be integrated so that customers can be linked to a transformer, meter and location and that new information uploaded to one system is automatically transferred to the other. In developing countries, utilities often do not have complete information on their customers and system assets, and their databases may not be integrated. Customers may need to be re-registered in the CMS and assets geo-tagged and properly coded and added to the NIS. Unfortunately, many utilities make large investments to implement sophisticated information systems but do not have the organizational structure or capacity to keep the databases up-to-date.

### **(2) Pinpointing losses through energy balancing:**

Once customer and asset registration is completed and the databases updated – even if just for one pilot feeder<sup>1</sup> area – the utility can perform energy balancing, provided that the feeders to the area have bulk meters that measure the supply of electricity to the area. Load balancing considers the electricity supplied to the area, as measured by the bulk meters, and “balances” this against the electricity consumed and paid for in the same area. The difference may be an indication of the amount of theft, provided that all meter readings to be balanced are read at approximately the same time. While prepaid metering helps to solve the collections problem it tends to diminish the effectiveness of energy balancing to identify areas of theft, due to the inability to fully match consumption at the user level with the feeder meter. In these cases,

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<sup>1</sup> A distribution network feeder is the power line transmitting electricity from a distribution substation to the transformers that serve the end load.

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rather than determine exact values of losses, utilities use energy balancing results to indicate areas of high losses where the utility should concentrate loss reduction efforts and resources. Utilities that lack adequate metering at the customer, transformer or even sub-station level and/or do not have complete customer, billing and network asset information will not be able to conduct energy balancing and calculate losses at any granular level. Rather, they may estimate losses at a network or country level and are therefore unable to pinpoint sources of losses, identify their root causes and implement targeted loss reduction initiatives.

### **(3) Developing organizational capacity:**

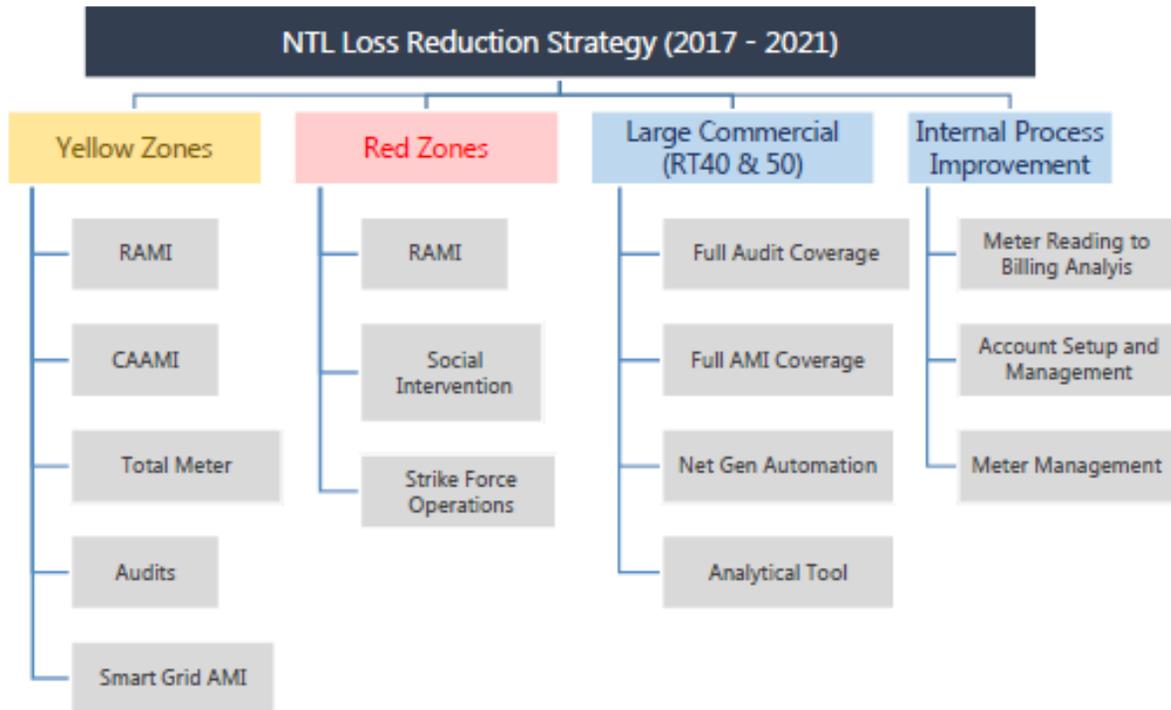
In addition to metering control points in its network and collecting accurate customer and network information, utilities must have the management and operational capacity to carry out robust loss analytics, map losses and root causes, and develop and implement targeted loss reduction strategies. To start with, utilities must utilize a standard loss calculation process across its network (rather than processes independently established and conducted by utilities' regional offices) and establish clear roles and business processes related to data collection and entry; database integration and management; meter procurement, testing and calibration; energy balancing; loss identification and prioritization; and regularization of illegal connections and fraud. This work requires a utility to have an organizational structure and capacity that enables efficient execution of these tasks; human resources, including trained field crews; manuals, guidelines and specifications that are consistent and enforced across the utility; and necessary equipment such as vehicles, meter testing labs, meters, and software. As detailed in this recent USAID research, utilities can also employ incentive schemes that offer monetary or non-monetary rewards to utility staff for achieving loss reduction targets. Another element of commercial losses related to organization capacity that is often underestimated, is internal theft of revenues and assets, particularly within utilities that have poor corporate governance and oversight. Few utilities in developing countries have structured processes for revenue assurance or conduct periodic audits of processes and activities within the revenue cycle.

### **(4) Developing roadmaps and strategies.**

An overall utility-wide assessment such as [this one](#) completed for the national electricity utility of Mozambique, can identify a utility's organizational strengths and weaknesses for pinpointing and addressing losses, and enhancing revenues. A utility's loss reduction strategy typically segments customers according to customer classes and prioritizes initiatives targeting industrial and commercial customers. This customer class represents the fewest number of customers but accounts for the largest source of revenues for the utility. Addressing fraud and irregularities in this customer class has the largest payback and is simplest given the fewer number of customers to meter, audit and inspect.

Some utilities break down residential into sub-categories in their loss reduction strategies, as done by the Jamaican Public Service (JPS).

**Figure 1: JPS Loss Reduction Strategy 2017–2021**



Source: JPS Annual Tariff Adjustment Submission for 2017 and Extraordinary Rate Review, May 2017  
[http://www.our.org.jm/ourweb/sites/default/files/documents/sector\\_documents/jps\\_annual\\_tariff\\_adjustment\\_filing\\_2017\\_rev.pdf](http://www.our.org.jm/ourweb/sites/default/files/documents/sector_documents/jps_annual_tariff_adjustment_filing_2017_rev.pdf)

As shown in Figure 1, JPS deploys different strategies depending on whether the customer is in a designated “yellow zone” or “red zone.” “Red zone customers” are considered unable to pay, reside in inner city and squatter settlements, and loss reduction strategies focus on “community renewal” projects implemented in partnership with the Government of Jamaica, Strike Force operations to remove illegal hookups, and Residential Advanced Metering Infrastructure (RAMI).<sup>2</sup> Losses in Red Zones typically exceed 70%. “Yellow zone” customers are considered able to pay and rather than have illegal hookups, conceal theft through meter tampering and bypasses which are more difficult to detect. Strategies for identifying and addressing Yellow Zone losses (as well as losses from commercial and industrial customers) include audits aided by AMI data and data analytics to enhance the probability of finding irregularities upon field investigation. As done by JPS, it is critical to discern the root cause of losses and tailor solutions accordingly. The problems can be especially complex in low income communities where cutting off electricity service due to theft might only reduce losses in the short term as households will quickly re-connect themselves illegally.

<sup>2</sup> In 2009, JPS began installing RAMI which intends to deter theft by installing meters, which can be remotely read and controlled, in an enclosure box situated high on a utility pole. The associated communication system alerts JPS if the enclosure box is tampered with.

## (5) Testing, evaluating and scaling loss reduction initiatives.

Utilities are constantly looking for new and more effective approaches to detecting and controlling theft and fraud. Where the problems are intractable and the utility may lack capacity to address them, Governments and utilities may turn to the private sector for assistance. While it's beyond the scope of this note to discuss the range of electricity distribution Public Private Partnership (PPP) arrangements, it's worthwhile reviewing in Box 4 the positive experiences that India has had with distribution franchises, a model that can be effective where there is limited appetite for more extensive private sector control of utility assets and operations such as through management contracts, lease agreements, concessions and divestitures. Where such PPP arrangements are being considered by governments, loss reduction may become a critical component of a PPP strategy so as to make the utility more attractive to private investors by improving its financial viability and demonstrating that losses can be reduced.

### Box 4: Results of the Bhiwandi Distribution Franchise in Maharashtra, India

The 2003 Electricity Act enabled the Distribution Franchise (DF) model to be tested in Bhiwandi where the bid for a 10 year DF was won by Torrent Power in 2006. The selection of Torrent Power was based on the price bid for input energy to be paid to the Maharashtra distribution utility for power supplied by it to the franchisee. Torrent Power is responsible for metering, billing, revenue collection, and capital expenditures (subject to regulatory approval). The results are impressive as depicted in the table below, and DFs have since been awarded in Agra and Kanpur (in Uttar Pradesh) and in Nagpur, Aurangabad, and Jalgaon (in Maharashtra).

Parameters	2006/07	2010/11
AT&C losses (%)	58.0	18.5
Number of transformers	2,254	2,611
Distribution transformer failure rate (%)	42	3
Metering (%)	23	98
Load-shedding (hours/day)	10–12	Not available
Collection efficiency (%)	58	99
Megavolt-amperes of reactive power installed	0	160
Number of feeders	46	86
Extra high voltage capacity	550	1,000
Customers	174,000	235,000
Use of information technology	None	SCADA, AMR

Source: Mukherjee 2013.

Note: AMR = automated meter reading; AT&C = aggregate technical and commercial; SCADA = supervisory control and data acquisition

Source: World Bank (2014) More Power to India, The Challenges of Electricity Distribution

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***This section focuses on activities utilities might take in tackling losses in communities that are particularly difficult to serve such as urban squatter settlements.***

While customers in these areas consume little electricity, they are large in number and continue to grow with increasing urbanization. Furthermore, prior to being regularized, these customers can consume or waste significant amounts through theft and not having to pay for what they consume or waste. From a development perspective, legal, safe and reliable electricity service is a necessary precondition for improving their economic and social condition. Challenges for utilities include informal governance structures, a culture of non-payment, limited ability to pay, lack of land tenure, poor housing construction, narrow streets and alleys, and frequent violence against utility staff.

Below is a series of example steps a utility and its donor partners may consider in providing legal, reliable power to these difficult to serve communities (See these USAID publications for more details and country case studies).

**a. Building a positive relationship with the community.**

Utilities typically have to overcome a very negative community perception, often resulting from previous utility efforts to police the community and tear down illegal “hookups” (with them often reappearing the next day). As a first step, the utility must establish contact with the true community leaders (these may not be formal government officials) and negotiate the scope of the loss reduction program. Community meetings and outreach through media should also be conducted to keep neighborhood households and businesses fully informed of the program and for the utility to learn of and address customer concerns. Listening to community concerns and adapting the program to local conditions is a critical first step. For example, community leaders in the favelas in Sao Paulo, Brazil demanded that the utility, AES-Eletropaulo, only charge a small flat fee for service. While AES-Eletropaulo could not meet this demand, they came to a compromise and charged households for up to 150kwh/month for the first six months (with actual consumption and charges shown on the bill) as a means of educating customers and transitioning them from not paying (almost all had illegal hookups) to paying for service. During this design phase, a baseline study may also be conducted through surveys and/or house to house visits to assess housing conditions, number and condition of appliances, anticipated consumption, and ability to pay, which will help frame the loss reduction program.

## b. Technical solutions.

After conducting cost-benefit analyses and considering the physical conditions of housing and infrastructure in the service territory, utilities will select from a range of technical solutions in upgrading the distribution network and service drops to customers (detailed descriptions of these can be found in the [USAID Toolkit: Optimal Feeder Level Connection](#)). These investments, which become technologically more advanced as the utility matures and gains capacity and resources, will meet multiple performance objectives beyond loss reduction, including improved service quality and making it easier for customers to pay.

Below are common technical approaches utilized in low-income urban areas:

- (i) *Prepayment meters* are frequently used as they enable customers to purchase electricity when they are able to (rather than receive a bill at the end of the month when they may not be able to afford it), better control their consumption by watching their remaining credit on the prepayment meter reader and turning off lights and appliances, and negate the need to assign addresses or deploy utility staff to read meters, deliver bills and disconnect customers for non-payment. Split prepayment meters enable the utility to place the meter high on the pole where it's less accessible and position the reader inside the home where it can be monitored and used to manage consumption. These are more expensive but more effective in combating theft. (Note split meters can also be used for post-paid consumers.)
- (ii) *Automated Meter Reading (AMR)<sup>3</sup> or AMI<sup>4</sup>* may be deployed to enable the utility to carry out functions remotely, including disconnecting and reconnecting customers and collecting consumption and power quality data.
- (iii) *Anti-theft network configurations* include using twisted cable in secondary network and bi-coaxial cable in the service drop, which are difficult to tap; extending the Medium Voltage (MV) line as long as possible or placing it below Low Voltage distribution lines; and placing the meters high on a pole in a box with an alarm that will alert the utility when it is tampered with.
- (iv) For houses that are in poor physical condition, *readyboards* may be used as an alternative to internal house wiring (as described in [this article](#), USAID is working with JPS to test readyboards in a low income urban community in Kingston, Jamaica).

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<sup>3</sup> According to the Demand Response and Advanced Metering Coalition, AMR is defined as a “system where aggregated kWh usage, and in some cases demand, is retrieved via an automatic means such as a drive-by vehicle or walk-by handheld system.”

<sup>4</sup> The Federal Energy Regulatory Committee (FERC) defines AMI as “a metering system that records customer consumption hourly or more frequently and that provides for daily or more frequent transmittal of measurements over a communication network to a central collection point.”

### c. Social solutions.

Loss reduction activities that engage customers and respond to their needs are critical for both designing and sustaining reductions in losses. There are many alternative solutions to reducing losses in low-income communities. To identify which would work best in a community, it's critical for the utility to understand the local culture of the community, the formal and informal leaders, the positive and negative social and economic forces at work, and the most appropriate form of communication and approach. The utility must also identify which actions will be undertaken over the longer term to sustain loss reduction. A common problem is for utilities to discontinue activities prematurely or not monitor results to better understand what is working or not.

The following are example initiatives that educate customers, facilitate customer payment, and help build a positive rapport between the utility and the community.

- (i) *Using NGOs and/ or local “agents” as community liaisons.* In establishing a new relationship with the community, the utility may choose to work with a local NGO which will act as an intermediary and facilitate communication with the community leaders and residents. As the loss reduction program moves from design to implementation, utilities may hire local residents to act as their “agents” to conduct door to door visits, educate customers on safety and how to reduce consumption to make service more affordable, identify possible cases of theft, billing errors, and bring any customer complaints to the utility. As described in [this article](#), Tata Power in New Delhi, India hired more than 800 local women from 223 slums to act as utility liaisons and encourage bill payment. As a result, Tata saw 183 percent increase in revenue over five years from these areas with minimal cost to the company.
- (ii) *Community outreach.* Utilities use a wide range of approaches to communicating with the community about loss reduction program activities. These may include door to door visits, town meetings, radio, and print and digital media. The format, content, and timing of these outreach efforts will depend on the social context of the target community. For example, literacy rates, shift or seasonal work that might impact hours at home, and gender dynamics are factors that might shape the design of an outreach campaign.
- (iii) *Making it easier to pay.* Utilities have a suite of options for helping reduce the costs to low-income customers of an electricity connection and helping customers pay for service, sometimes with the assistance of Government subsidies. Upfront connection fees, which can range in SSA from about \$2 - \$400,<sup>5</sup> can be a barrier to low-income customers. Governments and donors (see [World Bank Output Based Aid program](#)) may decide to help subsidize these costs and/ or utilities can offer financing with

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<sup>5</sup> World Bank (2013) Connection Charges and Electricity Access in Sub-Saharan Africa, Policy Research Working Paper.

customers paying the connection fee through their bill in small payments over a period of time. Per [this latest update](#), USAID is assisting Cote d'Ivoire and Tanzania with exploring options for reducing the costs of connection and internal wiring. Facilitating customer payment for service can be achieved by ensuring that bill payment or purchase of prepayment credits can be done at convenient locations or via mobile phone and customers are educated on how they can reduce their consumption and increase affordability of service through conservation measures described below.

- (iv) *Energy conservation.* Loss reduction programs typically include customer education on energy conservation and efficiency and may go so far as replacing households' incandescent bulbs with CFLs or LEDs or even inefficient refrigerators (as an example, see [this Brazil AES-Eletropaulo case study](#)). Utilities are incentivized to undertake these to prevent reversion to theft as a result of inability to pay for consumption. Recent USAID research has found that the price signal associated with regularization combined with energy efficiency measures can reduce consumption (and associated GHG emissions) by about 40% in the short term. Consumption may rise once customers have access to reliable and high quality power and economic conditions improve. More sophisticated utilities which have accurate billing and collections data have sometimes used their client database and payment history as a platform for micro-credit schemes, offering credit to low income customers in good standing for (more efficient) appliances and equipment and other services. A well-known success story is Codensa-Hogar, a micro-credit scheme launched by the utility Condensa serving Bogota, Columbia, which after six years had lent \$280 million and had 700,000 low income clients, many of which had never had access to credit before.<sup>6</sup> In 2009, Codensa sold Codensa Hogar for \$290 million to Multibanca Colpatría but continued its role of marketing and collecting payments.<sup>7</sup>

While many utilities in developing countries still struggle with high losses, there are a number, particularly in Latin America and Asia, which have had a high degree of success in reducing them. A success story that is often shared is of TPDDL's experience described on the following pages.

By assisting utilities in improving their operational and financial performance, USAID can help transition countries' power sectors away from dependency on Government and donor subsidies towards self-sustaining and revenue-producing sectors that attract private investment and meet their countries' needs for accessible, reliable and affordable power.

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<sup>6</sup> Marquez, Patricia and Carlos Rufin (2011) Private Utilities and Poverty Alleviation: Market Initiatives at the Base of the Pyramid, p. 142.

<sup>7</sup> International Finance Corporation, From Gap to Opportunity: Business Models for Scaling Up Energy Access, p 109.

## TATA POWER DELHI DISTRIBUTION LIMITED (TPDDL) - A LOSS REDUCTION SUCCESS STORY<sup>8</sup>

*In mid-2002, Delhi's government began reforming its power sector, including unbundling and creating six successor distribution companies. One of these became Tata Power Delhi Distribution Limited (TPDDL or Tata), a joint venture between Tata Power Co Ltd (51%) and the Government of Delhi (49%). This case study describes how TPDDL was able to make dramatic improvements in the utility's operations – bringing total losses down from 53.1% in 2002 to less than 10% in 2015. Lower tariffs were maintained as approximately half of the average tariff increase was offset by the reduction in losses – a benefit that was passed on to customers.*

Tata first tackled theft by large industrial and commercial customers, bringing losses down from 53% to 15% in most areas over five years. To bring down losses ever further, Tata had to tackle theft in 220 slum areas (or JJ Clusters) in its service territory where losses were as high as 89%. TPDDL took a multi-prong approach in these densely populated areas where residents rarely paid and often lacked proof of residence.

First, Tata set up a Special Consumer Group focused on improving the socio-economic conditions of residents in the JJ Clusters and thus their ability to pay. Tata supported such activities as insurance schemes, children's education, women's literacy program, scholarships, medical facilities, vocational training, and drug rehabilitation. They also reduced connection charges to a third of the current connection fee, enabled connection fees to be paid through the bill, loosened proof of ID requirements, waived outstanding debt, and instituted "lifeline" rates for consumption under 200 kWh/month. As described above, Tata hired residents from the JJ Clusters to be ambassadors, read meters, collect bills and encourage payment. To help deter theft and enable customers to control their consumption, Tata installed prepayment meters and made the low voltage lines as inaccessible as possible. These measures led to an increase in metered connections from 40,000 in FY 2008-2009 to 175,000 in FY 2014-2015, a ten-fold increase in billed demand to \$20 million, and improved socio-economic conditions for about 1 million low income people.

*The total impact of Tata's initiatives to reduce losses and improve performance has been dramatic. From FY2002-2003 to FY2014-2015, the customer base more than doubled from an initial 600,000 to 1.4 million and overall revenues rose from US \$133.4 million to US \$990 million. During this period, Tata has paid about \$58 million to its shareholders, including the Delhi Government. Had reforms not taken place, the drain on the government budget is estimated to be about \$2.3 billion based on prior year losses. It's worth noting that Tata invested over \$620 million from 2002 – 2015 in upgrading its network, a sum that many utilities that are struggling financially would not be able to make, at least not at the same rapid pace. Nonetheless, Tata provides an example of what can be achieved when strong utility leadership deploys resources and fosters innovation in tackling the many challenges to reducing losses.*

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<sup>8</sup> Sinha, Praveer (CEO and MD of Tata), The Power of Public-Private Partnerships to Turn Around Dysfunctional Utilities: The Case of Tata Power Delhi, World Bank Blog and USAID Loss Reduction Toolkit.

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## RESOURCES

[USAID Smart Utilities Website](#)

[Innovative Approaches to Slum Electrification](#) (USAID)

[Reducing Non-Technical Electricity Loss through Employee Incentive Schemes](#) (USAID)

[Transforming Electricity Consumers into Customers: Case Study of a Slum Electrification and Loss Reduction Project in São Paulo, Brazil](#) (USAID)

[Financial viability of electricity sectors in Sub-Saharan Africa : quasi-fiscal deficits and hidden costs](#) (World Bank)

[Reducing Technical and Non-Technical Losses in the Power Sector](#) (World Bank)

[USAID Toolkit: Optimal Feeder Level Connection](#)

## ABOUT THE AUTHOR



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