

Reducing Technical and Non-Technical Losses in the Power Sector

Background Paper for the World Bank Group Energy Sector Strategy

July 2009

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Acknowledgment

This paper was prepared as a background paper for the forthcoming World Bank Group energy sector strategy. Pedro Antmann of the Energy Unit of the World Bank prepared the paper.

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Acronyms

AMI	advanced metering infrastructure
ANEEL	Agência Nacional de Energia Elétrica
APSEB	Andhra Pradesh State Electricity Board
CMS	commercial management system
EDF	Électricité de France
IRMS	incidence resolution management system
IT	information and technology
MIS	management information system
MVD	medium voltage distribution
NDPL	North Delhi Power Limited
PBR	performance-based regulation
PPIAF	Public Private Infrastructure Advisory Facility
PRT	portable reading terminal
SMIP	strategic management improvement plan
SOE	state-owned enterprise

Units of Measure

km ²	square kilometers
kWh	kilowatt-hour

Reducing Technical and Non-Technical Losses in the Power Sector

Objective

This document reviews experience with efforts in developing countries by private as well as state-owned electricity companies to reduce total losses in transmission and distribution and provides examples of sustainable reductions.

1. Losses in electricity supply

In electricity supply to final consumers, losses refer to the amounts of electricity injected into the transmission and distribution grids that are not paid for by users.¹ Total losses have two components: technical and non-technical. Technical losses occur naturally and consist mainly of power dissipation in electricity system components such as transmission and distribution lines, transformers, and measurement systems. Non-technical losses are caused by actions external to the power system and consist primarily of electricity theft, non-payment by customers, and errors in accounting and record-keeping. These three categories of losses are respectively sometimes referred to as commercial, non-payment, and administrative losses, although their definitions vary in the literature.

Metering and billing for electricity actually consumed by users is integral to commercial management of an electricity utility. Another critical task is collection of the billed amounts. Effective performance in both functions is critical to ensure the financial viability of the company. From the operational point of view, metering-billing and collection are separate functions and they require specific management approaches.

2. Sustainable optimal reduction of technical losses and elimination of non-technical losses

Optimization of technical losses in electricity transmission and distribution grids is an engineering issue, involving classic tools of power systems planning and modeling. The driving criterion is minimization of the net present value (sum of costs over the economic life of the system discounted at a representative rate of return for the business) of the total investment cost of the transmission and distribution system plus the total cost of technical losses. Technical losses are valued at generation costs.

Technical losses represent an economic loss for the country, and its optimization should be performed from a country's perspective, regardless of the institutional organization of the sector and ownership of operating electricity utilities. Although each case has its specific characteristics, depending on the current and future values of generation costs, some general comments can be made. Energy experts agree that, in the next two decades, global prices of primary energy resources (oil and other fossil fuels) will be rising in real terms. In its *World Energy Outlook 2008*, the International Energy Agency forecasts world oil prices rebounding to about US\$130 (2007 U.S. dollars) per barrel in 2030. Other forecasts differ in absolute values, but not in the upward tendency of energy prices. On the investment side, prices of equipment in the electricity sector (generation, transmission and distribution) steadily rose this decade until the global

¹ Customers are those consumers who have a commercial relationship with the electricity supplier within the applicable regulatory framework. Users of electricity, on the other hand, include customers as well as those who are not customers but nevertheless consume electricity through theft or by unofficial diversion from another customer.

financial crisis that began in the 3rd quarter of 2008. Against these price trends, the total costs of technical losses tend to exceed investment costs of transmission and distribution equipment required to reduce them to their optimum value, more so where a significant portion of generation is based on fossil fuels. This tendency is accentuated if environmental costs of power generation (harmful local pollutants as well as greenhouse gas emissions) and increasing difficulties in achieving social acceptance of new power plant construction (regardless of fuel type and technology) are taken into account.

Non-technical losses represent an avoidable financial loss for the utility. Although it is clear that the amounts of electricity involved in non-technical losses are being consumed by users that do not pay for them, experience shows that a significant percentage of those amounts (in some cases more than 50 percent) becomes reduced demand when those users have to pay for that electricity,² because they adjust their consumption to their ability to pay for electricity services. That reduction in demand has exactly the same effect as a reduction in technical losses: less electricity needs to be generated. Thus, from the country's perspective, reductions in non-technical losses are also positive.

From a social point of view, non-technical losses have several perverse effects. Customers being billed for accurately measured consumption and regularly paying their bills are subsidizing those users who do not pay for electricity consumption. There is a wide range of situations creating non-technical losses. A classic case is a theft of electricity through an illegal connection to the grid or tampering of a consumption meter. But examples also include unmetered consumption by utility customers who are not accurately metered for a variety of reasons. In all the cases some level of poor management of the utility in execution of its operations is present.

Electricity theft is de facto subsidization of those who steal by customers regularly paying bills according to their consumption. The same usually applies in the case of unmetered customers, unless this situation is explicitly and transparently defined by the competent authorities and reflected in the legal and regulatory framework of the sector—in some countries some categories of consumers (e.g., agriculture users in India and Bangladesh) are unmetered and pay a fixed amount for electricity irrespective of the amounts consumed, which means in practice that they are subsidized by consumers in other categories, tax payers, or both. Depending on the financial situation of the power sector, the savings from reductions in non-technical losses could be channeled to a) reduce tax-payers subsidies or tariffs paid by customers, b) achieve an average tariff level allowing recovery of costs reflecting efficient sustainable performance (critical to assure service quality), c) subsidize consumption of selected categories of socially sensitive existing users, or d) extend access to electricity supply to currently unserved population (in general the poorest and socially unprotected).

3. Current situation in developing countries

Non-technical losses in the power sector are almost non-existent or negligibly small in developed countries, as most of the population can afford to pay tariffs reflecting costs of supply (even if they are higher than those reflecting optimized performance of the service providers). In contrast, although mixed, the situation tends to be significantly different in developing countries. Many electricity utilities in developing countries succeeded in significantly reducing or eliminating

² See section 4.3.2.

non-technical losses in electricity supply on a sustainable manner, but others continue to show high losses.

In all successful cases, a large share of non-technical losses was concentrated in users able to pay for cost-reflective tariffs. Thus, non-technical losses can be reduced with little loss of welfare, while their continuation jeopardizes the financial sustainability of the power sector and harms well-behaving-electricity consumers, taxpayers, socially disadvantaged segments, and the country as a whole. Elimination of those losses (with the exception unmetered consumption explicitly and transparently defined in the regulatory framework) should be a matter of high national priority for every country.

3.1 Latin America

High total losses were prevalent in most Latin American countries at the beginning of the 1990s, in a scenario characterized by poor performance of state-owned enterprises (SOEs), poor service quality, and low access rates. Average tariff levels were usually below the cost of supply (exacerbated by inefficiencies in the performance of the utilities, particularly high non-technical losses) and both government subsidies and tariff cross-subsidization (in general from industrial and commercial to residential customers) were the usual practices. A vicious downward circle or “low-level trap” was the norm, as external subsidies were just keeping inefficient utilities afloat while the quality of service to existing customers progressively worsened. As a consequence, the willingness of the population to pay for higher tariffs steadily declined over time, reducing the income source for the power sector and deepening the crisis.

From 1985 to 2000, Latin America was the region in the developing world that made the most significant advances in the comprehensive reform of the power sector. In 1982 Chile became the first country to introduce widespread institutional and regulatory reforms in its power sector, aimed at promoting efficiency and sustainability of existing operations and expansion of services. Reforms were initially applied to existing SOEs, but they were fully privatized in the second half of the 1980s as an important means of ensuring efficiency in sector operations within a well defined regulatory framework which was transparently applied and enforced. The results achieved were impressive and the current performance of some Chilean utilities shows higher efficiency levels than comparable companies in developed countries.

In the first phase of reforms Chile was followed by Argentina in the early 1990s and shortly thereafter by Bolivia and Peru. The second phase of reforms included Colombia and Brazil by the mid-1990s and several Central American and Caribbean countries (Dominican Republic, El Salvador, Panama, Guatemala, and Nicaragua) by the end of the decade. The reform of the electricity sectors was limited or almost nonexistent in Costa Rica, Honduras, Mexico, Paraguay, Uruguay and Venezuela. In all cases, reform components included unbundling of sector operations, introduction of competition in generation through the creation of electricity wholesale markets (which had mixed results), and privatization of existing companies (predominantly in charge of generation and distribution and retail).

The distribution segment the reform of the electricity sector has produced largely positive outcomes. Privatized companies achieved substantial increases in overall efficiency (operational and financial) by cutting technical and non-technical losses and improving service quality to existing customers. The results obtained in the expansion of services to population without

access to electricity supply were mixed. Some successful cases, clearly led by Chile, coexist with others showing very limited achievements in the field.

The Chileans took advantage of being the pioneers in improving the efficiency of their privatized companies. They participated in the privatization processes of distribution companies in Argentina, Brazil, Peru, and Colombia, and became the new owners and operators of some of the most important utilities in those countries. Immediately after takeover of each company they implemented their in-house approach for improving performance, which was progressively refined and updated, incorporating the operational tools and the know-how they had to develop to overcome the challenges present in each specific environment.

3.2 East Asia

Chinese state-owned provincial electric power companies generally show good operational performance, in terms of service provided to existing customers, losses which are low, and connection of new consumers in rural areas. Performance of some companies in the richest South-Eastern region is excellent and comments made on the Chilean utilities are equally applicable.

In the last 10 years, Vietnam has achieved impressive results in improving operational performance of its state-owned electricity utilities and increasing electrification rates, despite a 15 percent annual growth in demand. Losses have been drastically reduced and service quality improved, particularly in urban areas; rural areas still need further improvement.

The Philippines has reasonably well performing private companies serving the capital and more than 100 small, poorly performing cooperatives in main urban areas characterized by poor operational and financial performance.

3.3 South Asia

State-owned utilities are highly predominant in the region. Quite recently Pakistan privatized the Karachi Electric Supply Company while all the other utilities remain state-owned. Poor operational and financial performance, with total losses exceeding 30 percent, is typical, including the Karachi Electric Supply Company. State-owned utilities are in the process of being restructured and corporatized in Bangladesh, starting from a poor operational and financial base. Total losses exceed 20 percent in all cases, although figures vary among the different companies.

In India, most of distribution activities are carried out by utilities owned by state governments. The exceptions are Reliance (former BSES) and Tata, two private companies serving Mumbai which have always been private. While both Reliance and Tata show total losses of about 11–12 percent,³ the performance of state-owned utilities is generally bad, with losses exceeding 30 percent in most cases. Seven states started reform and restructuring of their power sectors in the 1990s, involving unbundling and corporatization of state-owned utilities. Privatization of only six distribution companies has gone forward so far and three of those have failed. The state of Orissa was the first to unbundle its electricity companies in 1996, followed by three failed attempts at privatizing distribution companies. Privatization of the New Delhi Vidyut Board in

³ Information obtained from the website of the Maharashtra Electricity Regulatory Commission (MERC), available at www.merc.org.

July 2002 was an ambitious undertaking, given its more than 4 million customers and losses greater than 50 percent of all power purchased at the time of takeover by new private owners, Reliance and Tata. The privatized companies have reduced total losses markedly. The case of the North Delhi Power Limited (NDPL), described in section 4.3, is probably the most recent example of a great success in sustainable loss reduction using state-of-the-art management and information technology tools currently available worldwide.

A successful functional unbundling program from an operational perspective is restructuring of the Andhra Pradesh State Electricity Board (APSEB). This utility has unbundled and corporatized the units in charge of generation, transmission, and distribution, while maintaining state ownership of all entities. One transmission and four distribution companies were created. They managed to reduce transmission and distribution losses from about 38 percent in 1999 to 26 percent in 2003 and less than 20 percent in 2008—in large part through theft control, with the utilities regularizing 2.25 million unauthorized connections.

3.4 Former Soviet Union

In the 1980s, the performance of electricity distribution utilities of the countries in the former Soviet Union was characterized by universal access, reasonably acceptable service quality, but poor financial performance. High total losses and poor collection rates, due to weak metering, billing, and payment collection accounted for the companies' financial distress. Starting in the 1990s, most EU accession countries have successfully privatized their distribution companies. Ukraine and Georgia are moving in the same direction. However, the situation remains almost unchanged and the commercial performance of distribution companies is poor in Russia and most of the other countries in the former Soviet block.

3.5 Sub-Saharan Africa

A draft 2008 World Bank report⁴ describes the performance of the utilities in Sub-Saharan countries. The median utility in that region presents huge inefficiencies. Only 50 percent of electricity generated is paid for, due to a combination of low percentages of amounts of electricity injected in distribution networks being billed and low rates of collection of the billed amounts. The variation in performance is enormous, with the highest inefficiencies in Nigeria, where the utility is capturing only 25 percent of the revenues owed. Some recent studies have shown that hidden costs of distribution losses in Sub-Saharan Africa are usually more than 0.5 percent of GDP, and may be as large as 1.2 percent of GDP in some countries. The exceptions are the state-owned and operated utilities of Botswana and South Africa. Botswana Power Corporation has long provided reliable, high-quality service. It has expanded the network in both urban and rural areas, covered its costs and posed no burden on the government budget. It has also reduced system losses to 10 percent and earned a decent return on assets. Electricity losses in Botswana are lower than in South Africa, whose power sector is operated by Eskom, one of the largest utilities in the world, with about 15 percent total losses.⁵

⁴ AICD Flagship Report – 8. Power: Improving performance and Financing. Anton Eberhard, lead author.

⁵ Eskom Annual Report 2007, available at www.eskom.co.za/annreport07/annreport07/downloads.

4. Some relevant cases

This section describes some representative cases of successful and sustainable reduction of total losses in electricity distribution in developing countries, involving both private and state-owned companies.

4.1 Distribution companies in India

4.1.1- State-owned companies in the state of Andhra Pradesh

A successful unbundling program from an operational perspective is restructuring of the Andhra Pradesh State Electricity Board (APSEB), a government-owned vertically integrated power utility serving about 12 million customers in the State of Andhra Pradesh in India. The case is described in detail in a 2004 note published by the World Bank, and this section draws from that paper.⁶ APSEB suffered large and growing financial losses in the 1990s, amounting to Rs40 billion (US\$0.9 billion) by 1997. The utility's operational performance also deteriorated during the same period, adversely affecting the power supply. Power subsidies grew to 1.6 percent of state GDP, while public spending on health and education fell from 4.7 percent of state GDP in 1987 to 3.6 percent in 1998.

In 1998 the state government of Andhra Pradesh initiated a comprehensive phased reform program in the power sector to establish a new legal, regulatory, and institutional framework; develop a new industry and market structure; and privatized distribution. Andhra Pradesh enacted an electricity reform law; unbundled the utility into one generation, one transmission, and four distribution and retail companies; and established an independent regulatory commission responsible for licensing, setting tariffs, and promoting efficiency and competition.

The new distribution utilities inherited a weak system of accounting for electricity dispatched and consumed and rampant electricity theft that, together with revenue leaks and other factors, undermined their financial performance. In fiscal year 1998/99, only 42 percent of the electricity flowing into the distribution system was metered and billed. The balance was accounted as transmission and distribution losses and consumption by unmetered agricultural customers numbering about 2 million. The unverifiable estimates of sales and losses allowed the utilities to camouflage inefficiency and theft, and thus to deflect public scrutiny of their poor performance, hide political and bureaucratic corruption, and obscure the public debate about the agricultural subsidy. The theft occurred in several ways, including tapping power lines and tampering with or bypassing meters, often with the connivance of utility staff. Revenue leaks resulted from weaknesses in metering, billing and collection, internal control systems, and enforcement of the disconnection policy.

The first step in the reform was to acknowledge theft. An energy audit program led to more realistic estimates of transmission and distribution losses (38 percent in fiscal year 1998/99, up from an earlier estimate of 18 percent) and recognition of non-technical losses (or unmetered consumption—theft and others). Public expectations from the reform program, and regulatory reviews that increased public accountability, brought theft and losses under sharper public scrutiny.

⁶ "Reforming the Power Sector. Controlling Electricity Theft and Improving Revenue." Bhavna Bhatia and Mohinder Gulati. World Bank Group. Private Sector Development Vice Presidency. Note Number 272. September 2004. Available at <http://www.eapirf.org/MenuItems/Resources/Papers/Energy/rsrc303.pdf>.

In January 2000 the government launched a comprehensive plan for controlling theft and improving accountability based on four measures: enacting a new law to address electricity theft, strengthening enforcement mechanisms, reorganizing the anticorruption function in the utilities, and reengineering business processes to improve management control and customer service.

In July 2000 the state government amended the Indian Electricity Act of 1910 to make electricity theft a cognizable offense and impose stringent penalties. A separate law, unprecedented in India, provided for mandatory imprisonment and penalties for offenders, allowed constitution of special courts and tribunals for speedy trial, and recognized collusion by utility staff as a criminal offense.

Advance preparations ensured that the government was able to constitute special courts and appellate tribunals as soon as the new law came into force. The utility service areas were divided into 24 “circles” coinciding with the state’s 24 administrative districts. A special court and police station were established in each circle to ensure rapid detection and prosecution of electricity theft. And the state police and anticorruption units of other government departments were directed to support utility employees in inspections to control theft.

The government also initiated institutional changes in the distribution companies. Their anticorruption department was strengthened by promoting its head from an advisory to an executive position on the board and the organizational structure was modified to strengthen the department’s coordination with other departments. In addition, the anticorruption department’s procedures were made simple and transparent. Inspecting officers provide an inspection report with an identification number to customers on the spot and carry numbered receipts so they can accept payments of fines. Police stations provide public notification of all cases of theft. And a new tracking system was implemented to follow the progress from inspection to payment of a fine or prosecution. More than 2,000 inspection teams were deployed throughout the state to launch the theft control drive.

Business processes were reengineered with the support provided by a new management information system (MIS), called the “customer analysis tool”. As other systems for commercial management of utilities, the system uses a centralized customer database to analyze metering, billing, and collection performance, allowing monitoring of staff’s performance against their targets. It also generates focused management reports that enable timely corrective action. Proper use of such powerful management significantly increased the detection of irregularities while protecting the rights of honest consumers (initially non-discriminatory police raids and neighborhood searches affected honest customers).

Process reengineering included all dimensions of commercial service to address existing customers’ complaints. Connection delays were drastically reduced and the utilities introduced a spot billing system to allow meter reading in the presence of customers, thereby minimize billing complaints. They also established a special cell in each operation circle to authorize new connections and address customer complaints and opened collection centers at convenient locations and mobile collection centers in rural areas. Computerized customer care centers—serving as one-stop windows for handling complaints, receiving payments, and following up on electricity supply problems—were set up.

Improved processes supported by the commercial MIS were complemented by well targeted investments in information-technology (IT) supported metering, comprising high-quality meters, remote meter reading instruments, and advanced communications technology. More than 2 million high-quality meters for electricity customers were installed in two years, compared with a past average of 600,000 a year. High-accuracy meters were installed for large and medium consumers and the old meters recalibrated and installed for small users. To support energy auditing, electronic meters with data logging devices and facilities for transmitting the data through a satellite communications system were installed on all medium-voltage distribution feeders. Meters were also installed on the transformers serving mainly agriculture customers to allow better estimation of their consumption and thus provide much needed transparency in a sensitive and controversial area; individual metering was not implemented in order to minimize resistance.

In the initial phase the theft control program focused on large consumers. Dedicated feeders were constructed to supply large industrial customers, which were also provided high-quality, tamper-proof electronic meters. Protective boxes were installed on transformers. Meter reading instruments were provided to inspection teams to download monthly data, allowing analysis to identify customers whose monthly consumption varied by more than 2 percent. Irregularities in metering and billing were found for about 15 percent of the 23,000 industrial connections and 10 percent of the 36,000 non-technical connections inspected in fiscal year 2000/01. Inspection of residential customers focused on medium-voltage feeders with high line-losses and on 114 towns accounting for 53 percent of consumption and 60 percent of revenue.

The government launched a communication program through media ads, posters, and videos, and a public outreach program through visits by special teams and regular public meetings with utility managers. The outreach campaign deployed about 600 teams to conduct town hall meetings in all settlements with more than 200 residents. The teams informed people about the proposed new law and the penalties for electricity theft and gave everyone the opportunity to obtain an authorized connection on the spot after paying a connection fee. They also explained the utilities' deteriorating financial situation and the effect of electricity theft on their costs and tariffs. The credibility of the communication and the government's political resolve to combat theft were tested when some politically powerful people (including a member of the legislature) were charged with theft of electricity. The cases went forward, and the proof that even the most powerful were subject to the new law, and that utility officials would be protected from interference, generated broad support for the program among the public as well as utility employees.

Execution of the plan was closely monitored. All district offices were linked to headquarters through the satellite network for quick transfer of data and district administrators and engineers submitted daily reports on the connections regularized and fees collected. In order to assure sustainability of results, the information system developed to monitor the plan was integrated into the management control systems of the companies, becoming the tool used for regular monitoring.

Results obtained were impressive. Transmission and distribution losses were reduced from about 38 percent in 1999 to 26 percent in 2003, in large part through theft control, with the utilities regularizing 2.25 million unauthorized connections. More importantly, this trend continued in the following years, demonstrating the sustainability of the approach. For fiscal year 2007/08 the distribution companies applied to the Regulatory Commission for a loss allowance of 18.7

percent above expected sales, while the losses allowed for the determination in the tariff order were 18.5 percent.

4.1.2- North Delhi Power Limited (NDPL)

North Delhi Power Limited (NDPL) was founded on July 1, 2002 through public/private partnership framework as a 51:49 joint venture between Tata Power and Government of Delhi. NDPL distributes electricity in the north and northwest parts of Delhi and serves a population of about 5 million people spread across 510 square kilometers (km²). It has a registered consumer base of about 1 million, a peak load of 1,180 million volt-amperes, and an annual energy consumption of about 6,200 gigawatt-hours.

Six years into its inception, NDPL has achieved impressive results in reducing total losses, moving from 53 percent at takeover in July 2002 to 18.5 percent at the end of 2008 and 15 percent in April 2009. According to information published on the company's website (www.ndplonline.com) and data obtained in personal meetings with Commercial Direction, the various measures taken to achieve this loss reduction include the following:

- Implementation of advanced metering infrastructure (AMI) for metering, reading, and monitoring consumption of all consumers with demand of 15 kilowatts and above, who represent 30,000 users, or 3 percent of total, but contribute to almost 60 percent of the revenue
- Installation of medium voltage distribution (MVD) networks in theft-prone areas, with direct connection of each consumer to the low voltage terminal of the supply transformer
- Replacement of old erroneous electromechanical meters with accurate electronic meters
- Energy audits up to the distribution transformers (medium to low voltage) level
- Aggressive enforcement activities with scientific inputs and analysis
- Public participation in controlling theft through the concept of "social audit"
- Collaboration with non-governmental organizations for creating awareness in slums regarding the dangers associated with direct tapping of electricity from live wires.

NDPL's Commercial Direction considers implementation of AMI for large consumers the reason explaining 90 percent or more of the quantitative results obtained, as the other measures are at less advanced implementation stages.

In addition, the company is taking advantage of the application of a performance-based multi-year tariff regulatory regime. Performance targets (including allowance on total losses) are set by the regulator for a four-year tariff period. If the company meets or surpasses those targets, it is allowed to keep the surplus profits (additional revenues and reduced costs) until the next tariff period. NDPL is operating consistently below the allowed total losses. Thus, the difference between the allowed revenue (based on the performance target) and the actual amount of energy purchased is retained by the company as an additional profit. For the next tariff period, the regulator will set new targets for losses starting from the values actually achieved by NDPL. The performance-based, multi-year tariff regulatory regime has shown to provide the right incentives to the regulated companies to improve their performance.

4.2 Privatized distribution companies in Central America: DELSUR in El Salvador

Prior to the reforms carried out in the late 1990's, Central American governments were providing large subsidies to their power sectors, with total distribution losses often exceeding 30 percent of

generated electricity. Most of the government-owned entities were poorly managed and financially weak, and politically-oriented regulation did not give them the right incentives.

Between 1996 and 1998, El Salvador, Guatemala, Panama, and Nicaragua approved electricity laws that created a completely new regulatory framework for the power industry in each country. In broad terms these new frameworks called for vertical unbundling, open transmission access, creation of competitive generation markets, and privatization of the distribution segment of the industry. The unbundling and privatization of the distribution sector was completed a few years later. This process included separation of the SOEs operating in each country into several distribution companies and their privatization.

There are five major distribution companies operating in El Salvador, which were privatized at the end of the 1990s. Four of them are owned by the U.S. group AES, while the fifth (DELSUR) was purchased by the U.S. group PPL Global Inc. for about US\$180 million in 1998. At that time the company had about 194,000 customers located in the south central area of the country including a part of San Salvador, the capital city. Five years after takeover, the number of customers served by DELSUR had reached 255,000, who consumed about 25 percent of the country's total electricity demand.

PPL's experience and knowhow in the utility business significantly improved overall management and operational efficiency of DELSUR. The company quickly moved to a customer-oriented management approach, the main actions of which included the following:

- Implementation of a call center operating 24 hours every day
- Expanding or improving customer care centers throughout San Salvador to increase contact with customers and to be more responsive to their concerns
- Incorporation of IT-based MIS and execution of field campaigns to develop commercial functions (metering, billing, payment collection, customer service through call centers and at care centers), including the construction of a new customer database incorporating historical consumption, billing and payment records, and other relevant commercial parameters. This enabled more efficient and transparent development of commercial functions, which led to a sustained improvement of billing and collection rates.

DELSUR reduced total losses from 15 to around 7 percent in just five years,⁷ and the loss reduction has been sustained to this day. In the two periodic tariff reviews performed in 2002 and 2007, the national electricity and telecommunications regulator SIGET set progressively tighter targets on total losses, which were achieved by the company in the 2002–2007 tariff period (the tariff period beginning in 2007 runs until 2012).

4.3 South America: Enersis of Chile as a benchmark for operational efficiency in electricity distribution

4.3.1- Introduction

As mentioned in Section 3, Chile in 1982 became the first country to introduce widespread reforms in its power sector. The private Chilean distribution companies have taken advantage of being the pioneers in improving their operational efficiency. Enersis, the largest group in the

⁷ Information obtained from the website of the Electricity and Telecommunications Regulator of El Salvador, SIGET, available at www.siget.gob.sv.

country which is also involved in electricity generation, owns Chilectra Metropolitana, the company in charge of electricity distribution in the country's capital Santiago. Parameters characterizing operational performance of the company are impressive, even better than those of comparable utilities in developed countries. In particular, total losses are about 5 percent, after a continued and sustained reduction from 22 percent at the time of takeover.

Enersis successfully participated in the privatization processes of distribution companies in Argentina, Brazil, Peru, and Colombia. It became the new owner and operator of some of the largest utilities in those countries: EDESUR (Argentina), EDELNOR (Peru), AMPLA and COELCE (Brazil), and CODENSA (Colombia). The main characteristics of each company are summarized in Figure 1. Immediately after the takeover of each company Enersis implemented its in-house approach for improving operational performance, which was progressively refined and updated incorporating the operational tools and the knowhow they had to develop to overcome the challenges imposed by each specific environment. Total losses were reduced in all cases, as shown in Figure 2. These results are all the more impressive given the very challenging conditions in which the electricity companies have had to operate in almost all cases.

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Figure 1: Main characteristics of distribution companies operated by the Enersis group

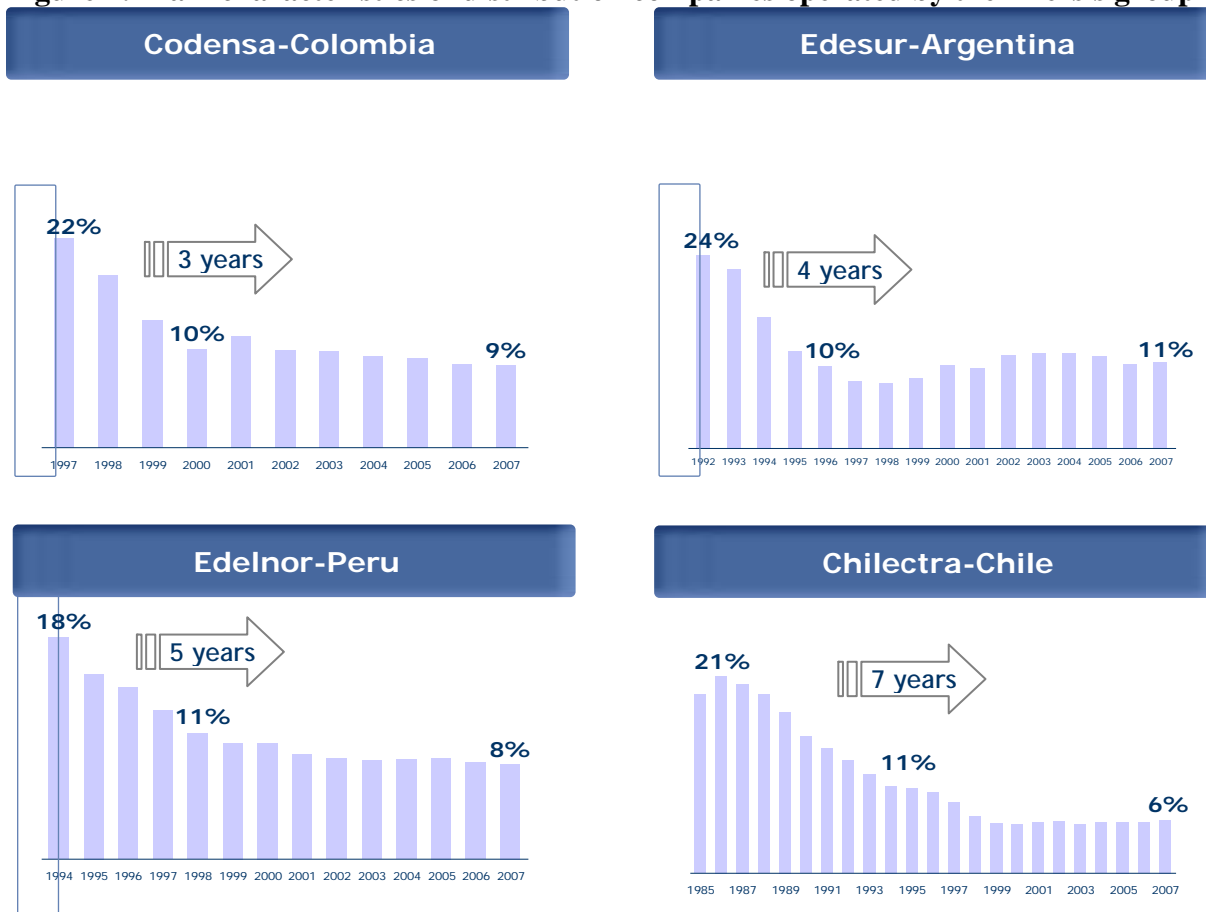


Figure 2: Results of Programs for Reduction and Control of Losses in Enersis Group Affiliate Companies⁸

4.3.2- The case of CODENSA (Bogotá, Colombia)

The approach followed by Enersis to achieve and sustain excellent results in reducing losses in very complex political and socio-economic situations is based on a strategic model and related action plans and programs, which are adapted to the specific circumstances in which the distribution company operates. Based on the concepts of customer segmentation and geographic sectorization of the served area, the strategic model focuses on eliminating any irregularities in electricity supply to all existing electricity users (including customers and other users currently not captured in the company's customer database) and sustaining these results over time. The strategic model includes actions on the electricity grids and customers' connections needed to improve service quality. Other components allow clandestine users to become customers of the utility. The model is implemented through a set of programs, specific for each segment of consumers and geographic zone, aimed at achieving and sustaining "normal" commercial behavior of all the customers of the company. The Enersis group terms realization of normal commercial behavior "market discipline."

The case of CODENSA, the company serving the capital Bogotá, provides important emerging lessons, taking into consideration the simultaneous existence of great political and socio-economic challenges.

CODENSA was created in 1998 when the vertically integrated utility (EEB) serving Bogotá was unbundled and privatized as three separate companies: EMGESA (generation), EEB (transmission), and CODENSA (distribution). CODENSA was privatized using a capitalization model where Enersis (Chile) and ENDESA Spain (which purchased all Enersis assets in 1999) invested about US\$1,226 million for the distribution market covering Bogotá, which represented about 22 percent of the total demand.

At the time of the takeover of CODENSA by Enersis, Bogotá was an extremely dangerous city, with significant presence of political guerillas, paramilitary squads, and groups involved in drug trafficking almost everywhere. Physical risks were highest in some low-income areas, due to strong presence of those irregular groups which abused the extreme needs of the population living there.

The restructuring process of CODENSA is a remarkable success story. The company reached a productivity level of 2,100 customers per employee, through downsizing combined with outsourcing of a variety of services associated with network expansion and maintenance, information technology, and installation of metering devices. The quality of service was significantly improved: average interruption time was reduced by more than 70 percent (from 6.3 hours in 1997 to 2 hours in 2002) and the average of interruption frequency was reduced by more than 70 percent (from 11.4 in 1997 to 3.1 in 2002).⁹

⁸ "Latin American Electricity Markets, Regulation, Renewables and Energy Efficiency. Perspective from an operator," ENDESA. Presentation made at the World Bank by José María Calvo-Sotelo, Senior Vice-President for Regulation and Corporate Development, Endesa Latin America, Washington DC, February 24th, 2009.

⁹ Experience in reduction and monitoring of non-technical losses in Latin America. Enersis-Endesa. Presentation to government officials of the Dominican Republic by José Inostroza (CEO-Codensa), February 2005

Total distribution losses steadily declined from 22 percent in 1997 to 10 percent in 2000, 9.68 percent in 2004, and 9 percent in 2007 (Figure 2). Equally important, 51.8 percent of 1,518 gigawatt-hours a year of non-technical losses at the time of the takeover translated into a permanent reduction in demand, while the remaining 48.2 percent provided an additional revenue to the company. The combined economic impact of those effects on the company was about US\$82.4 million. Implementation of a strategic model and related action plans designed by Enersis, which are described in the following paragraphs of this section, made the above achievements possible.

4.3.2.1- Fields of action of the strategic model

The strategic model applied by Enersis to achieve and sustain **market discipline** comprises actions in regulation, commercial management, technical management, training and management of external contractors (outsourced services), community engagement, IT, and punitive actions.

In the field of **regulation**, main actions include working together with the sector political authorities and regulator to achieve

- A tariff structure that would allow financial sustainability of efficiently managed distribution companies
- Tariff rates reflecting costs of efficient supply meeting service quality standards, assuring a fair and reasonable equilibrium between electricity consumers and service providers
- Generation of sufficient funds to subsidize low-income and other customers, using means set by the government: tariff rates and/or additional charges paid by selected categories of customers, government budget, grants, or a combination of those schemes
- Use of technologies assuring environmentally sustainable and low-cost supply.

Main actions in **commercial management** comprise

- Integral management of metering, reading, billing, collection, disconnection-reconnection due to unpaid bills, and inspection of meters
- Implementation of policies for customer service and programs for payment of old debts and commercial regularization
- Increasing the number of points of contact for customer service to move the company closer to its clients
- Marketing programs aimed at creating awareness that electricity is a commercial good with a price
- Implementation of communication programs to provide customers with transparent information on their rights and obligations.

Main **technical actions** include

- Construction of distribution networks less vulnerable to tampering and irregular connections
- Systematic field assessments looking for irregular connections, tampered or damaged consumption meters, unmetered consumers (both customers and irregular users)
- Use of boxes to ensure that the consumption meters are properly sealed and cannot be tampered with
- Use of boxes to seal customers connections
- Monitoring public lighting service
- Monitoring operational condition of installed seals.

Training and management of external contractors include

- Assuring ethical behavior of contracted workers
- Continuous training and provision of working tools (including safety equipment)
- Implementation of databases including documentation of workers with unethical behavior
- Certification of contractors based on quality, environment, and occupational health and safety criteria
- Implementation of procedures for monitoring execution of contracts for outsourced services, including auditing of representative samples.

Community engagement is an important area where the following actions need to be taken:

- Set direct and open contact with communities, their leaders, and the authorities involved in order to create awareness about the fact that electricity is a commercial good with a price and that electricity consumption should be rationalized and efficient.
- Design and execute campaigns about the culture of regular payment of electricity bills, preservation of electric infrastructure, and behavior to avoid electrocution.
- Develop programs for orientation and training of children living in low-income homes.

Investments in **information technology** comprise

- Incorporation of MIS to support commercial and technical functions and shared services
- Construction and regular updates of reliable databases for each MIS, based on field activities aimed at checking its consistency with physical reality
- Progressive application of automated meter reading devices for reading and monitoring consumption of large and medium consumers
- Systematic field action on irregular service conditions detected through the commercial MIS
- Permanent regularization and incorporation of users to the customer database.

Punitive actions refer to

- Working together with justice departments to ensure effective action in cases of electricity theft
- Systematic presentation before Justice of the cases involving large consumers
- Ensuring police action when required
- Recovery of old debts in selected cases through judicial actions
- Public information on main cases of electricity theft, in general involving well-known social agents, to promote social condemnation.

4.3.2.2- Specific programs for reducing losses developed by CODENSA

CODENSA implemented three main programs to achieve and sustain over time customer discipline by customer type and geographic zone (Figure 3). Specific activities were designed and executed for the following segments:

- Large industries and big commercial customers, supplied by high- and medium-voltage lines
- Medium commercial and small industries, supplied by medium-voltage lines
- Residential customers, supplied by low-voltage lines

- Irregular users in low-income areas, usually supplied by low-voltage lines.¹⁰

Main activities carried out under the programs comprised

- Investments to regularize supply to 170,000 users in low-income areas
- Investments to replace or renovate distribution networks and individual connections of 110,000 existing customer connections located in areas with high theft
- Installation of 164,000 meters for previously unmetered customers
- Replacement of 156,000 damaged or tampered meters
- Comprehensive field assessment on the physical condition of supply to 7,000 largest consumers
- Full regularization of cases where corrective action was needed
- Creation of an organizational unit within the company to attend to all technical and commercial aspects of the relationship between the utility and its large customers.

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Figure 3: Programs in strategic model for reduction of losses in CODENSA

4.3.2.3- Permanent action plans

Once the execution of the programs for regularization of the served market was completed, they were complemented by other permanent plans aimed at assuring maintenance of loss reduction. Those plans include

- Creation of an organizational unit in charge of coordination of all activities
- Periodic field inspections
- Updating mechanisms and technologies to avoid theft
- Implementation of programs to negotiate with clients with long-standing debts or suspected of stealing electricity
- Improving customer service
- Improving the quality of consumption metering
- Legal and communication actions to discourage theft and enhance the culture of regular payment for the amounts of electricity actually consumed.

5. Is private sector participation a necessary condition for success?

Latin America and the Caribbean is the region having the largest number of privately operated utilities in electricity distribution, followed by Europe and Central Asia; other regions have fewer private utilities. A recent WB-PPIAF publication¹¹ examines a data set of 160 electricity distribution companies under effective private management control and 90 SOE counterparts over more than a decade of operation. That database covers, as comprehensively as possible, all the electricity distribution companies that had private sector participation between the beginning of the 1990s and 2002, together with a set of similar state-owned utilities, and made meaningful—“like with the like”—comparisons. The number of companies in each region (both private and state-owned) and related percentages of the sample are shown in Table 1.

¹⁰ The voltage of the line connecting the customer is a function of the size of consumption. Large customers such as large factories are connected to high-voltage lines. The voltage of the line connected decreases with decreasing consumption.

¹¹ “Does PSP improve performance in electricity and water distribution” by Gassner, Popov, and Pushak, December 2008, available at www.ppiaf.org/content/view/486/462/.

Table 1: private and state-owned electricity distribution companies in the sample

Region	Private sector participation		SOE	
	% of sample	Number	% of sample	Number
Latin America and Caribbean	69	111	44	49
Europe and Central Asia	22	35	21	23
Sub-Saharan Africa	6	9	18	20
South Asia	3	2	3	3
East Asia and Pacific	1	1	2	2
North Africa	1	1	2	2
Total	100	160	100	90

The study compares performance of private sector firms with that of SOEs. The comparison shows that the private companies had higher labor productivity and operational efficiency, clearly outperforming comparable companies in the database that remained state owned and operated. Private sector operation was associated with a reduction of distribution losses of 11 percent, an increase in electricity sold per worker of 32 percent, and an increase in the bill collection rate of 45 percent, within five or more years of privatization.

Although results obtained from the study seem quite conclusive in general terms, they need to be complemented with an analysis of the specifics of each case. PSP appears to be a good option to improve operational performance of distribution utilities (in particular to obtain a sustainable reduction of total losses) if the institutional and regulatory framework provides the right incentives.

An analysis of the main cases in the Latin America and Caribbean region shows that all the reforming countries implemented performance-based regulation (PBR) for setting multi-year tariffs (applied for periods of four to six years at a time) and monitoring compliance with service quality standards by electricity distribution utilities. Revenues considered for setting tariffs of each regulated company have included an allowance for total losses valued at the price of purchased electricity. If the company managed to operate with lower total losses than the allowance, it kept the difference as an additional profit until the next tariff review. If it failed to achieve the loss reduction, the gap between the allowed loss and the actual loss had to be covered by the company, representing a loss for its shareholders. This mechanism was extremely effective in Argentina, Chile, El Salvador, and Peru.

An informative case is the history of two distribution companies serving Buenos Aires, the capital of Argentina. EDENOR and EDESUR were created in the first half of 1992 by dividing the existing SOE, SEGBA, into two utilities serving very similar markets and geographic areas. This allowed the government and regulator to apply horizontal competition and compare the performance of the two companies. In July 2002, the two companies were privatized through a competitive call for bids, where the price to be paid up-front for running a 99-year concession was the bidding parameter. Bidding documents included a very detailed concession contract. It set very clear rules for the regulated service, both in terms of tariff regime and service quality. In particular, it set an initial tariff period of 10 years, with predefined tariff rates that allowed for total losses of 12.5 percent. At the time of the privatization bid, total losses of SEGBA were about 30 percent.

The French group Electricité de France (EDF) paid about US\$450 million for EDENOR and the Chilean company Enersis about US\$500 million for EDESUR. As the new owners lost money until operating losses were reduced to 12.5 percent and earned additional profits from the moment the losses were below 12.5 percent until year 10, there was a tremendous incentive to reach that target. Enersis applied and improved upon all the knowledge acquired in similar circumstances acquired in the company's operations in Chile and started reducing losses rapidly, to 12.5 percent in just three years. In contrast, EDENOR initially showed a lack of knowledge of commercial operation in developing countries by managers who have operated only in developed countries. In particular, problems with metering, consumption reading, billing, and collection are almost never encountered in developed countries and meters are often read every month to as infrequently as every 12 months, billing is based on average consumption, and collection is made through automatic debits of customers' bank accounts. In developing countries, it is critical to perform all commercial cycle operations every month or at the most every two months and the revenues of the company depend on effective receipt and payment by each customer of his bill. The attempts by EDENOR before the Secretary of Energy to increase the allowance for losses set in the concession contracts failed from inception, as at the same time EDESUR was reducing losses significantly in manageable areas (those where the utility can perform operations without significant constraints). This, together with the high amount paid up-front to run the concession, forced EDENOR to change the approach and implement action plans similar to those executed by EDESUR. Local managers replaced the European experts in those assignments and they successfully met the targets.

Another interesting aspect of the Buenos Aires case is the incentive-based approach adopted for regularization of electricity supply to 655,000 low-income residential end-users living in slums within the served areas. Those neighborhoods suffered from low service quality, high losses, and low collection rates when EDENOR and EDESUR started their operations, and the utilities initially faced significant constraints on their operations. One year after the takeover, the national government, the municipalities of the zones where the slums were located, EDENOR, and EDESUR signed a framework agreement for regularizing electricity supply, setting specific rights and obligations for each party.

The slums included in the regularization program were grouped in three categories, according to the level of infrastructure development (such as the presence of internal streets), and a specific technical solution for the supply of electricity was defined for each category. On the one end, bulk supply with a single wholesale meter was adopted in the slums with almost non-existent infrastructure. On the other hand, a completely conventional connection was built for individual customers living in neighborhoods that were sufficiently developed to make this option technically feasible. Once the requisite infrastructure facilities were in place, the electric utility had the obligation to build conventional connections for all the users living there.

The national and municipal governments assumed the obligation to support field activities to be performed by the distribution companies, to provide subsidies for financing the work needed to regularize power supply to the slums, and to pay to the distribution companies the recognized amounts of non-collected debts corresponding to electricity supplied during the period between the takeover and signing of the framework agreement. The amount of subsidies provided by the national and municipal governments was equal to the taxes that the companies had to pay for the sale of electricity to regularized consumers. This approach gave the companies the right incentive for regularization, as payment of subsidies depended entirely on the existence and

actual amount of electricity sold to regularized customers. This approach proved to be very successful, demonstrating the effectiveness of right incentives and a proper allocation of risks.

Other country cases in Latin America also offer important lessons. In Brazil there are 64 electricity distribution companies regulated by the same national regulator ANEEL (Agência Nacional de Energia Elétrica). They show enormous dissimilarities in market size, geographic area, and other key parameters. The smallest companies serve about 10,000 customers in small cities or rural areas, while the two largest companies serve more than 6.5 million customers. ELETROPAULO serves San Paulo, an area of 2,000 km² with a large population, while CEMIG serves 470,000 km² in the state of Minas Gerais comprising large, medium, and small cities as well as extended rural zones. Between 1996 and 1998, about 30 of the distribution companies, representing about 70 percent of total electricity sales in the country, were privatized, under a PBR multi-year tariff regime which was also applied equally to all the other companies remaining as SOEs. Allowed losses for the first tariff period were based on the losses of the regulated utility at the time. They were generally not very tight. But the new owners of the privatized utilities immediately took advantage of the opportunity to increase their profits through reducing losses below the allowance considered for setting tariffs. In the period 2003–2005, ANEEL implemented the first tariff review for each of the 64 distribution companies, conducting a specific process for each for setting the new tariff rates. At that time, almost all the private companies had reduced losses to well below the allowance for the first tariff period preceding the review. The results for the SOEs were mixed. Those serving rich areas in the south of the country had improved their operational performance, in particular in reducing losses. The performance of the companies operating in low-income zones in the north remained poor. In those cases, financial losses caused by application of PBR were absorbed by the state governments (that is, paid for by taxpayers living in the state). Table 2 shows the evolution of total losses of a set of Brazilian distribution companies during the first tariff period.

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Table 2: Evolution of total losses in Brazilian distribution companies in the period 1998-2003¹²

In this context, two cases are particularly informative. One is CEMIG, the SOE owned by the state of Minas Gerais. The company achieved remarkable loss reduction, as a result of a comprehensive reengineering of the distribution and retail functions driven by customer-oriented service and incorporation of IT tools for management. CEMIG was considered for a long time as a mark of excellence in hydropower generation and high-voltage transmission, representing the top of Brazilian engineering in the field. But customer orientation was not a concept embraced within the company. The governor of the state of Minas Gerais strongly opposed the privatization process carried out by the national government. And he believed that the best way to support and strengthen his position was to show a first-rate SOE, symbolizing excellence not only in hydropower and transmission engineering but also in customer service. He achieved remarkable success. As CEMIG has minor private shareholders and its shares are traded in both Brazilian and New York stock markets, the profits obtained from its performance in the first tariff period exceeding the standards set by PBR in the concession contract were transparently known and allocated. Thus, CEMIG is a clear example of an efficiently performing SOE, due to a combination of a right institutional and regulatory framework with political leadership.

¹² Prepared by the author with information obtained from ANEEL's "website": www.aneel.gov.br

The opposite case is LIGHT, the company serving the city of Rio de Janeiro, one of the richest areas in the country. Total electricity losses were historically very high and were 30 percent at the time of its privatization in 1996. This was due to a combination of poor management with some social characteristics specific of the population living in the state (electricity theft was widespread in all the zones served by the company, comprising the high-, medium-, and low-income segments). EDF, the new owner, failed to reduce losses in the first tariff period, as it kept the same management as when the company was a SOE, which tended to focus on explaining and justifying a lack of progress than on achieving results. High allowance (based on historic losses) helped EDF to avoid significant financial losses, but prevented it from making potentially large profits. In 2005 EDF sold LIGHT to a Brazilian private group, without having achieved any significant reduction in total losses: the losses remained at about 30 percent, almost the same as at the time of the takeover.

The analysis of the cases in sections 4 and 5 show that private sector participation is not a necessary or sufficient condition for success in sustainable reduction of losses by electricity distribution companies.

6. Critical conditions for success

In a handbook¹³ prepared by PA Consulting Group for USAID in November 2004, the critical conditions for success in sustainable reduction of losses in electricity distribution, emerging from a comprehensive review of international experience in developing countries, are identified. They are summarized in “four axioms of reform,” extracted from that handbook and discussed below.

1. **Accountability.** Accountability means authorizing a person or an entity to take certain actions, establishing a target against which the success of those actions may be measured, measuring that performance, and rewarding or sanctioning the person or entity based on performance against the target.
2. **Ownership through participation.** The government and utility must generate the impetus for reform. Outside help can facilitate change, but the leadership for change must come from within. The utility and government must believe in the process of change, own it, and internalize it in order to make reform work.
3. **Holistic approach.** Success depends in part on creating and motivating institutions to fulfill their roles in a restructured sectoral environment. The approach should encompass technical aspects, processes, and human capacity and willingness to produce results. Targeting one aspect without considering how that element interacts with or influences the balance of the sector can lead to ineffective, suboptimal, or even destructive results.
4. **Enhancement of social development and equity.** The reform program must continually justify itself in terms of social benefits achieved, and ensure that these results are communicated clearly to the public.

Those critical conditions must be reflected in the design and implementation of action plans that include the following:

¹³ “Improving Power Distribution Company Operations to Accelerate Power Sector Reform”. PA Consulting Group. November 2004, available at http://pdf.usaid.gov/pdf_docs/PNADJ549.pdf.

- *Market segmentation.* When total losses are high, say 25 percent or higher, large consumers usually account for a large fraction of the losses. This is referred to as the Pareto effect whereby a very small percentage of customers account for a disproportionately high fraction of the total revenue (for example, 1 percent of customers, typically operating in the wholesale market, contributing to 30 percent of the company's revenue). Economic incentives for collusion between these large consumers—for whom monthly electricity bills run into thousands of U.S. dollars—and utility employees in charge of reading their meters are extremely high. Experience shows that collusion in this segment is a significant problem in poorly performing companies and should be the first to be tackled in any action plan aimed at reducing losses. In the 1990s the solution to this problem was based on systematic field inspection of large consumers' premises, performed by the most reliable (in terms of honesty and technical abilities) employees of the service company.
- *Publicity of cases of theft detected through inspection.* This has been shown to be a very effective tool, as large consumers are in general well known and have much to lose if their fraudulent behavior is exposed. They steal electricity until the utility decides to “name and shame” the customer, because the cost of social condemnation far exceeds the savings from not paying fully for electricity consumption.
- *Reengineering of business operations and availability of reliable information.* MIS allows reengineering of regular operations and provides reliable and transparent information within the company as well as to the government and other external stakeholders. This assures sustainability of the results obtained through field campaigns by enabling substantially faster analysis and processing of data and generating reliable reports allowing quick corrective action. Generation of risk profiles of customers based on their historical consumption and payment patterns enables utility staff to prioritize and target non-payers and potentially recurrent thieves. While in the initial stage the practice may be to inspect entire neighborhoods to detect a few thieves, once a majority of fraudulent activities have been identified and tackled, the strategy can move to target inspections of defaulting customers and high-loss service areas identified through the information systems. The paradigm shifts from “inspect and detect” to “detect and inspect,” making the approach socially acceptable and sustainable over time.
- *Credibility of the communication and the government's political commitment to combat theft.* A real test of commitment is when some politically powerful people (who could even include ministers and members of the legislature) are charged with theft of electricity. If these cases go forward unimpeded, it demonstrates to the public that even the most politically powerful are not above the law and that utility officials would be protected from interference. Such public demonstration of commitment to combat theft generates broad support for the program across the public as well as utility employees. Social legitimacy to combat theft at every level is boosted if ordinary people perceive that the most powerful are the first target.

7. The way forward: strategies and plans to achieve sustainable reduction of non-technical losses

7.1 The fundamentals

While the fundamentals concerning the legal and institutional aspects of the successful initiatives implemented in several developing countries in the 1990s remain fully valid, reengineering of business processes must be dynamic and continually adapt to technological evolution, particularly with respect to IT. Because IT-based management tools available in the 1990s were limited, the utilities implementing successful action plans to reduce losses had to include systematic monitoring through field inspections as a critical component to promote market discipline. However, impressive developments in IT since then provide distribution utilities with extremely cost-effective management tools for optimizing operations related to electricity supply and customer service.

7.2 The technological revolution: automated meter reading and advanced metering infrastructure

Electricity distribution is a sector where technological evolution is gradual, at least in the network assets. However, there is a field in which progress in the last few years has been rapid, at a speed typical of the telecommunications sector. Remote metering, reading, and monitoring of electricity consumption are referred to as advanced metering infrastructure (AMI). Drastic reductions in prices of metering and telecommunication equipment is making their adoption economically feasible, starting with large consumers and gradually applying AMI to medium and small ones. The effectiveness of the tool to detect and discourage theft and other ways of unmetered consumption is enormous, as shown by the recent experience in developing countries (including the Dominican Republic, Honduras, and Brazil).

Large-scale application of AMI can significantly contribute to sustainable development and efficient performance of power sector in developing countries. AMI provides powerful tools to reduce total losses and increase collection rates. Its application has the following positive impacts (in general significant in developing countries):

- a) *“Watchdog” effect on users.* Users become aware that the utility can monitor consumption at its convenience. This allows the company fast detection of any abnormal consumption due to tampering or by-passing of a meter and enables the company to take corrective action. The result is consumer discipline. This has been shown to be extremely effective with all categories of large and medium consumers having a history of stealing electricity. They stop stealing once they become aware that the utility has the means to detect and record it. Recent experience in such countries as the Dominican Republic and Honduras shows that consumers stop stealing if they face the risk of social condemnation. More importantly, they do not go back to stealing electricity. AMI can be implemented at very low costs both for medium- and low-voltage consumers, using mobile phone networks, power line communication, or other means of remote communication between the meter located at the customer’s premises and the company’s office where the reading is received and processed. These measures can significantly increase the revenues of utilities with high non-technical losses.
- b) *Enhancement of the company’s corporate governance and anti-corruption efforts.* Instances of theft by large consumers usually involve collusion between them and meter readers. Corruption is also likely to occur in operations of service disconnection related to unpaid bills. Implementation of AMI eliminates those field operations (meter reading and service disconnection) and makes information on consumption transparently available to

the users and managers in the company, greatly enhancing governance and reducing corruption.

- c) *Implementation of pre-paid consumption.* Pre-paid consumption is generally a very good commercial option for low-income consumers. AMI enables replication in the power sector of the tremendous success of pre-paid consumption in the mobile phone industry—key to expanding use of mobile phones in developing countries. There are dozens of cases of very poor countries in Africa, Asia, and Latin America with a booming mobile phone industry, often by-passing land lines. According to the International Telecommunication Union, by end-2007, about 60 percent of mobile subscriptions in the whole world were prepaid.¹⁴ The percentage of prepaid mobile subscriptions is well above 60 percent in poor countries; although prepaid tariffs tend to be more expensive (per minute) than postpaid tariffs, they are often the only practical payment option available to low-income users who might not have regular income. Implementation of AMI, together with a commercial management system (CMS), makes pre-paid consumption of electricity possible. Credit bought by consumer is loaded in his account in the CMS; many options are available for purchase and loading, including use of mobile phones. The company can easily implement operational procedures allowing the customer to have access to the remaining credit, receive alert messages from the company when the credit is about to expire, buy new credit, receive disconnection message, etc. The company can apply remote disconnection and reconnection included in the AMI devices used for low-voltage consumers in cases of credit expiration and non-renewal in the same way pre-paid mobile phones work. The AMI approach for pre-paid consumption has several significant advantages compared to the classic pre-paid card meters widely used in South Africa and other countries. Two very important ones are (1) significantly lower hardware costs, and (2) permanent monitoring consumption allowed by AMI, which is not possible with the classic card meter. With a card meter, the company has no information on real time consumption while the user has credit and the cardholder can by-pass the meter without being detected, unless field inspections are performed. AMI pre-paid consumption has recently been implemented in Brazil by the company AMPLA, an affiliate of the Enersis group.
- d) *Elimination of losses in non-manageable areas.* AMI is a key component of the approach called medium-voltage distribution (MVD), used for construction and operation of electricity networks used to supply consumers located in areas where access of the service company is constrained due to safety or other reasons. MVD was designed and implemented by Enersis in its affiliate company AMPLA serving 2 million customers in the Brazilian state of Rio de Janeiro. In MVD networks every individual consumer connection starts directly from a medium- to low-voltage transformer, a low-voltage grid is eliminated, and is laid above the medium-voltage line. AMI is used to read consumption, with meters located in a shielded panel close to the supply transformer. A user has several ways to access the meter readings, including a repeating display located on his premises. AMPLA has implemented the MVD solution to supply 300,000 consumers living in areas where crime associated with drug trafficking makes regular operations almost impossible.

¹⁴ Measuring the Information Society – The ICT Development Index 2009 – International Telecommunication Union, available at www.itu.int/publ/D-IND-ICTOI-2009/en.

- e) *Demand side management* to maximize efficiency in electricity supply and consumption. Permanent AMI (in general applied to medium and large consumers in all categories including residential, both in developed and developing countries) through smart grids allows optimization of electricity consumption by informing users on real-time prices, start and end of peak periods, accumulated consumption, alerts, etc. Recent experience, both in developed and developing countries, shows that medium and large consumers are responsive to clear and timely information on pricing options.

7.3 The strategic management improvement plan for electricity distribution utilities in developing countries

Any plan for reducing losses in the future should make proper use of AMI, combined with management actions and investment. Synergy in the implementation of those actions can be maximized if they are assembled together as components of a strategic management improvement plan (SMIP) of an electricity distribution utility, the five key components of which are described below.

7.3.1- Component 1: Achieving “zero non-technical losses and 100 percent collection” in electricity supply to large consumers connected to high- and medium-voltage networks

In general, sales of electricity distribution companies are characterized by the Pareto or the “ABC” Law. A small number of large consumers (seldom more than 1 percent of total) represent more than 30 percent of the revenue of a distribution company. This group consists of all consumers supplied at high- and medium-voltage levels and the largest ones connected to low-voltage networks. It is crucial for the financial health of the company to ensure full billing of, and full payment by, 100 percent of its large consumers. The initial objective is zero non-technical losses related to electricity consumed by large consumers supplied at high and medium voltage. As shown in section 4, this has been achieved by many utilities in Latin America through a combination of good management practices and application of IT tools. Declining costs of the AMI tool make possible to broaden the scope of the objective to include large consumers connected to low-voltage networks using the approach described in the steps below.

Step 1: Create a large customer department as an organizational unit within the commercial department

A large customer department will be responsible for managing all aspects of a utility’s transactions with large customers. Its manager must be an expert with wide professional experience in the commercial management of large customers.

Step 2: Design and implement a detailed field assessment on the current situation of all consumers supplied by high-voltage and medium-voltage lines, the largest low-voltage customers, and potential irregular users in these categories.

The conditions of all large consumers—for example, 2000 kilowatt-hours (kWh) per month or more—must be accurately known. A comprehensive field assessment should be made based on visits to all points of supply. At each site being visited, the crew must

- a) Check the condition of electric connection (wires, meter, etc.)
- b) Determine actions to be executed for technical regularization of the connection
- c) Verify the commercial condition of the customer (active customer, etc.).

Step 3: Define and execute a plan to regularize supply where needed.

Based on the conclusions of the assessment executed in step 2, a plan aimed at regularizing all points of supply to large consumers must be designed. Regularization is not limited to the condition of the physical connection for electricity supply but includes commercial aspects. The distribution company should sign a new supply contract with each large consumer where shortcomings in metering, payment, or both, have been found.

A new database for those consumers should be created and regularly updated. The large customer department will have commercial agents. Each agent will manage all aspects, technical and commercial, of the contract between the distribution company and a group of large consumers. Each large consumer will be informed by the agent in charge that he will receive personal attention and will be encouraged to call the agent for any issue related to the service provided by the distribution company. In particular, commercial agents will be responsible for close monitoring of technical and commercial conditions of the supply to each large consumer on his list.

Step 4: Implementation of automated meter reading in all points of supply to regularized large customers

Functional performance of the set to be installed includes

- a) Permanent electronic metering of all parameters of electricity supply (voltage, current, power factor).
- b) Periodic transfer (daily or with any other desired frequency) of recorded data to a remote point (typically a commercial agency of the electric company) using existing facilities of a telecommunications company (wired or wireless links). Usually data are transferred once a day during night time, when communications lines are largely unused. This allows the electricity company to minimize costs for use of those facilities. But metering is done on-line: data can be collected at any time at the remote point.
- c) For low-voltage consumers, remote disconnection and reconnection of electricity supply are performed from the same point where the metering data are collected and analyzed. Current state-of-the-art technology enables remote disconnection and reconnection of electricity supply to low-voltage users at very competitive prices, less than US\$50 for the AMI set plus the disconnection and reconnection module.¹⁵ For high- and medium-voltage consumers, the devices (power breaker and auxiliaries) needed for remote disconnection and reconnection are usually expensive. In addition, commercial debts of those customers are managed on a case-by-case basis, and disconnection is rare. However, it may become economically feasible to formulate individually-designed interruptible supply agreements between the distribution company and the consumer, matching consumption with daily periods of cheap electricity prices or taking account of alternative sources of supply (self-generation) available to the customers.

It is advisable that each large low-voltage consumer be connected to an exclusive medium-voltage/low-voltage supply transformer, or at least have an exclusive shielded connection to the low-voltage terminals of a transformer built using a twisted or concentric cable. This makes it extremely difficult to attach irregular connections to this cable. The distribution company must

¹⁵ Information provided to the author by the CEO of the electricity distribution company Edenorte, Dominican Republic, corresponding to equipment purchased and installed by the utility in 2006-07.

clearly identify each connection and provide the information on the supply transformer to the large consumer concerned. AMI and the equipment for disconnection (electronic meter, disconnection and reconnection switch, communication modem, and auxiliary devices) must be installed in a sealed panel and located close to the transformer, between the low-voltage terminals and the connecting cable.

Steps 2 to 4 should be progressively applied for smaller low-voltage large consumers (500 kWh per month and more).

Step 5: Define and put in practice operational procedures for periodic systematic monitoring of electricity supply to large customers and for taking immediate corrective action for any irregularity detected.

Regularization of large consumers does not end with the execution of activities described in step 4. Stopping at step 4 is a serious mistake made by many utilities. Periodic and systematic follow-up of all regularized large consumer is a crucial task. Until remote metering is implemented, it implies that the crew in charge of regularization visits customers periodically and checks that the situation remain normal (no clandestine additional connections or tampering with metering detected). Once remote metering is implemented, inspections can be executed once a month or every time the data received daily show any abnormal patterns. It is recommended to complement inspections performed by the company's own staff with others developed by companies specializing in audits.

7.3.2- Component 2: Incorporation of a new CMS and related procedures for commercial activities.

In order to achieve sustainable good commercial performance, the distribution company must incorporate a state-of-the-art CMS allowing proper execution and monitoring of all activities related to

- Commercial cycle (regular metering, billing, and collection)
- Dealing with customers at commercial agencies or by phone (call centers)
- Disconnection and reconnection of electricity supply related to commercial debts
- Connection of new customers.

Incorporation of the new CMS requires building, maintaining, and regularly updating a reliable customer database.

7.3.3- Component 3: Incorporation of a new incidence resolution management system and related procedures for addressing customer claims caused by poor quality of electricity supply.

Efficiently performing distribution companies use an incidence resolution management system (IRMS), which is another IT application not directly related to loss reduction but which improves service quality. High service quality gives incentives for on-time payment of bills and helps reduce tampering with metering and damage to equipment belonging to the utility. IRMS is a highly effective tool for dealing with customers' complaints and improving the quality in electricity supply. It allows the company to minimize time elapsed between receipt of the claim and restoration of regular electricity supply and, at the same time, maximize efficiency in the execution of the activities that the company must perform for that purpose. Conceptual design of IRMS is based on setting a link between each point of electricity consumption and the electric networks involved in the supply. This allows quick identification of the potentially faulty components of the networks related to a claim presented by a customer and sending the

operational crews straight to those installations. This enables proper management of claims related to faults affecting a large number of consumers.

Effective implementation of the IRMS requires building and regularly updating a system database. Through a comprehensive field assessment, based on physical visits, network assets for supplying each customer are identified. These links between customers and network assets are the components of the IRMS database.

7.3.4- Component 4: Actual application of new procedures and rules for customer service

Incorporation of the new CMS must be complemented with the formulation and application of new operational procedures. Activities to be re-engineered include

- Commercial cycle: metering, billing (including delivery to customers), and collection
- Detection and regularization of fraud and unmetered connections
- Disconnection and re-connection of customers related to debts and/or fraud
- Dealing with customers at commercial offices
- Dealing by phone with customers reporting disruptions to electricity supply and other commercial matters through call centers.

Operational procedures for commercial activities must be developed at the same time as, and in full coordination with, the implementation of the CMS which is the main tool supporting execution of those operations.

Reengineering of commercial activities include, among other aspects, the following.

Metering

- a) Optimization of the reading routes.
- b) Incorporation of portable reading terminals (PRTs) where the consumption data are stored by an operator and automatically transferred to the CMS database at the end of each working day. This minimizes mistakes in those operations. In addition, historical consumption data of each customer stored in the memory of the PRT allow the reader to perform automatic checks on the consumption being recorded and ensure its accuracy. PRTs have been comprehensively used for metering by service utilities in Latin America since the beginning of the 1990s with excellent results.
- c) Selection and training of readers (own staff and/or outsourced).
- d) Regular monitoring through outsourced audits.

Billing

Billing is a typical function of the CMS. Bills are prepared and printed each night following the day the data of consumption are collected at the site, stored in the PRT and downloaded to the CMS database. Bills are ready to be distributed within 24 hours of data downloading.

Delivery of bills

- a) Optimization of the delivery routes.
- b) Potential outsourcing of the activity.
- c) Regular monitoring through outsourced audits.

Collection

The crucial issue in collection is the creation of an outsourced network of collection points, intended to maximize options offered for bill payment. It is important to understand that

collection is an activity essential for the survival of any company. But the expertise required (logistics, safety, etc.) is very specific and completely different from electricity supply. Therefore, collection should be outsourced to specialized companies. For customers with bank accounts and credit cards, bill payment through automatic debits should be strongly encouraged. This has significant benefits for the distribution company and has advantages for the customers, provided that they become convinced that they can rely on the accuracy of the amounts billed.

Detection of fraudulent activities and regularization of unmetered connections

- a) Optimization of operational procedures, supported by information provided by CMS.
- b) Training of operators.
- c) Execution of field campaigns and outsourced audits.

Disconnection of customers on account of debts and/or fraud and subsequent reconnection

- a) Optimization of operational procedures, supported by information provided by CMS.
- b) Training of operators.
- c) Execution of outsourced audits.

Establishing a call center for customer service

The distribution company must have a call center for dealing with customers by phone. The scope of this service must include both dealing with reporting of disruptions to electricity supply and commercial matters. Support provided by CMS and IRMS allows strengthening of this powerful tool. The guiding principle of phone customer service should be “the customer should be able to do all that can be done by phone, without needing to report to a commercial agency.” Design of a call center should include installation of special-purpose phones in several places of the served area, where the customers can make a toll free call to the call center. Current development of telecommunications allows this at low costs (inexpensive fixed wireless phones can be used). This option has been shown to be an excellent solution for ensuring access to call centers of low-income people without home telephone service.

7.3.5- Component 5: Regularization of supply to areas with high non-technical losses

High technical and non-technical losses are usually linked to a significant number of irregular connections to low-voltage lines (which are typically damaged as a result), customer connections in poor condition, faulty or non-existing consumption meters, etc. Those damaged assets must be replaced by new ones to achieve a sustainable regular electricity supply. It is necessary to conduct a detailed field assessment on the physical condition of those networks and identify

- Low-voltage lines and customers connections that need to be renovated
- New consumption meters to be installed (both to replace damaged devices and to place new ones at previously unmetered points of supply)
- Replacement and installation of new switchgear equipment (reclosers, disconnectors, etc.) needed to optimize network configurations and operation.
- Other infrastructure issues.

However, the technical solutions to be applied for renovation of low-voltage lines, customer connections, and metering devices must be defined and implemented according to the socio-economic characteristics of the users, as described in the following paragraphs.

- a) Regular (“manageable”) areas

For those consumers located in areas where the utility can perform operations without significant constraints, the solution involves improving electric networks and installing

electronic consumption meters, allowing remote metering, at each customer connection and also at the transformer supplying a group of consumers. This enables fast detection of irregular connections and fraud, enabling immediate corrective actions to be taken at the site and thus promoting consumers discipline in electric service. The concept supporting this approach is to avoid investments in network assets as much as possible and concentrate in remote metering devices because, once detected, fraud and theft can be eliminated with operations at the site. Comprehensive experience in almost all Latin American reforming countries show that consumer discipline is achieved in quite a short time if those irregular consumers become aware that the utility is able to make fast detection and take corrective action on fraud and theft.

b) “Unmanageable” areas

For those consumers located in areas where the utility cannot perform regular operations due to high crime or other constraints, regularization will be based on the construction of shielded networks for electricity supply and application of remote metering at each customer connection and also at the transformer supplying a group of consumers. This approach aims at impeding the construction of irregular connections to the networks and tampering with consumption meters. This has been recently implemented with very positive results in dangerous marginalized areas in Rio de Janeiro, Brazil, by the distribution company AMPLA. New shielded networks and metering sets following the MVD concept were built. MVD is an expensive solution requiring significant investments both in new shielded electric networks and remote metering devices. But it is the cheapest *sustainable* solution in these areas. Experience shows that a solution requiring the company to perform activities at the site does not work, as access to the area is constrained. Knowing that there is fraud and theft in an area does little if no corrective actions can be taken. Figures 4 to 6 show typical applications of the MVD concept.



Figure 4: Low capacity single phase medium-voltage to low-voltage transformer



Figure 5: Typical MVD arrangement



Figure 6: Shielded connections in MVD

7.4 Cost-effectiveness of actions in the SMIP – Barriers for implementation

7.4.1- Cost effectiveness of AMI

The rate of return and payback period of projects for implementing AMI for large consumers are usually extremely attractive. Although they depend on average tariff levels and amounts of electricity previously stolen, some basic figures illustrate their effectiveness. Installation of an AMI device on the premises of a high- or medium-voltage consumer, using the signals provided by the existing metering transformers, requires an investment of US\$300 to 400. This is equivalent to 3,000 to 4,000 kWh at an electricity price of US\$0.10 /kWh. In the case of a large user stealing this amount every month (not very significant for a customer with recorded consumption in the range of 10,000 to 20,000 kWh a month), the investment in AMI will be recovered in one month through billing of the previously unmetered consumption.

A more expensive solution for large high- and medium-voltage consumers consists of duplicating the metering system by installing a new one (including current and voltage metering transformers) outside the customer's premises. This solution is used when the customer does not allow the utility to access the existing metering system (owned by the utility company) to replace its components by new ones with AMI capabilities. This has occurred in certain regions of Brazil, where the justice system does not function properly. Installing a new system outside the premises costs about US\$5,000 per point of supply. Although expensive, even this solution is likely to be economic, because a large customer blocking access to the metering system on his premises is most likely to be engaged in fraudulent behavior and not paying fully for electricity consumed.

For large low-voltage consumers, supply and installation of an AMI device including a component allowing remote disconnection and reconnection costs about US\$50, equivalent to 500 kWh/month at an electricity price of US\$0.10/kWh. Depending on amounts previously stolen by the consumer, the investment could be recovered in a few days to a few months.

The above evaluations do not take into account avoided recurrent costs of field meter reading. This is the main driver for installing AMI in high-income countries, where the main issue is not theft but high labor costs. In developing countries, labor costs tend to be low compared to the amounts of recovered electricity and associated revenues.

7.4.2- Barriers for implementation of SMIP

There are no significant technical barriers for implementation of AMI. A communication link between the customer's premises and the operation center where the company collects metering data needs to be set. This can be done in several ways. One is always available: use of mobile phone lines, particularly at night when the usage rate is low. Even in very poor countries mobile phone service is now widely available, at least in main cities.

Introduction of MIS included in the SMIP has no technical barriers. It requires conventional hardware components (servers, terminals, personal computers, etc.) and a communication system based on telephone lines (fixed or mobile), fiber optics, or radio. Investment costs are relatively low compared to the benefits they bring to the utility's revenues: for CMS they are about US\$3–4 per customer, depending on the size of the company. The figures for IRMS are US\$2–3 per customer. Costs of field campaigns needed to build reliable customer databases must be added. They vary depending on the geographic dispersion of the served market and approach used for their execution. However, they hardly exceed US\$1.5 per customer for each system and can be lower if both campaigns are conducted simultaneously.

Main barriers for effective implementation of the SMIP usually arise from the strong reluctance on the part of managers and staff of monopolistic utilities to change their behavior and way of doing business. This is typical of, but not exclusive to, state-owned enterprises. As companies protected by monopolies do not face competition, management tends to be inefficient and information on business operations is usually limited and unreliable. That information is not transparently available across the organization, but tends to be kept by managers directly supervising field operations. This gives them effective power, as they become the "owners" of the information on field operations. A lack of transparency on management is the main reason for corruption, in particular in the activities involving significant amounts of money—reading consumption of large customers is probably the most relevant at the field level, followed by collection of old debts and customer service. As main components of the SMIP (AMI and MIS)

provide a lot of transparency to management and eliminate the power previously held by some managers and utility employees, there is usually some kind of passive opposition by the affected staff. As they cannot openly disagree with the objectives of the SMIP, they tend to delay its effective implementation. The solution is the same in all the cases: a team (“executive committee”) formed by reliable managers actually committed to improving the performance of the utility is appointed for the specific and exclusive purpose of implementing the SMIP. The committee must be strongly supported and led by the CEO.

SMIP is conducted in parallel with regular operations. Once each component of the project is implemented, new related operational procedures are put in place and the old ones displaced and retired. When SMIP finishes, a brand new transparent approach to efficient management is fully adopted. Managers in charge of SMIP usually become the operating managers of the renovated company. Feasibility of this approach is enhanced if SMIP is implemented in parallel with a flexible plan for retiring the (generally older) managers and employees in charge of managing the company under the old model. Experience shows that, once they see that the SMIP is moving forward, they very quickly understand that an attractive early retirement package is their best option. It is also the best alternative for the utility, as the main obstacle for successful implementation of the SMIP and improvement in operational and financial performance is removed.

8. Priority candidate countries

High losses in electricity distribution continue to be an issue jeopardizing sustainability of the power sector in several developing countries worldwide, including

- Sub-Saharan Africa (excluding Botswana and South Africa)
- South Asia
- Former Soviet Union countries (excluding EU accession countries, Georgia, and Ukraine)
- Latin American and Caribbean region: Dominican Republic, Haiti, Nicaragua, Honduras, Venezuela, Ecuador, six companies in the North and Northeast regions of Brazil.

The approach and measures described in this paper are fully applicable in all those cases.